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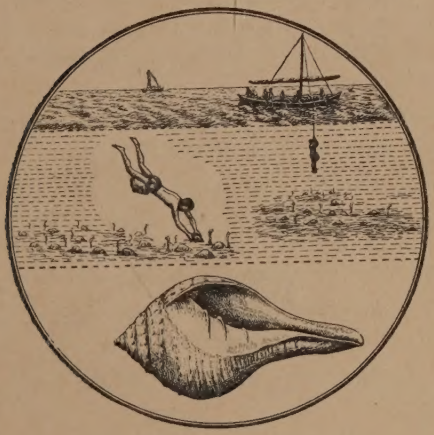

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5. All tables of contents, references to plates, legends to illustrations in the text, etc., must be in their proper places with page and plate numbers left blank. The position in the text for the text-figures must be indicated. Foot-notes should be numbered in Arabic numerals.

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(*Contd. on Cover page* 3)

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OBSERVATIONS ON THE PRAWN FISHERY OF THE COCHIN BACKWATERS WITH SPECIAL REFERENCE TO THE STAKE NET CATCHES

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Introduction

The long chain of backwaters extending along the central and southern parts of the Kerala State provides rich prawn fishing grounds, where fishing is carried out practically all the year round. The fishery is not confined to the backwaters only, but extends into the extensive networks of canals connected with them and also to the paddy fields bordering the ' Vembanad Kayal ' at about the middle of the chain. Though reliable statistics are yet lacking there is little doubt that the annual production may amount to several thousands of tons.

These backwaters stretch for the most part parallel to the coast-line and are separated from the sea in some places only by a narrow belt of sand, not more than a few hundred feet in width. In other places this sandy belt broadens out considerably, and may be a few miles across at the broadest points. There are a number of openings establishing communication with the sea, and facilitating the passage of water to and fro between the two. For about 4 months in the year from June to August the water, at least the upper layers in the deeper regions, is almost fresh (George, 1958) due to the large admixture of freshwater from rain, from land drainage and from the numerous streams opening into them. Later in the year there is a steady rise in salinity and in April to May it is only slightly below that of sea-water. The bottom in most regions is formed of mud containing large amounts of organic detritus.

Penæid prawns which contribute the bulk of the catches are known to breed exclusively in the sea, with the exception of an Australian species, *Metapenæus mastersii*. The larval development is completed in 2 to 3 weeks and the early post-larvæ or fry ascend into creeks, estuaries and backwaters in large numbers, where conditions for their early life and growth are presumably quite favourable. During the breeding period, which is fairly protracted in the case of some species, vast numbers of such fry pass into these

backwaters (Menon, 1951; George, 1958) and the rich prawn fishery of these waters consequently owes its existence to this habit of the fry.

The Cochin backwaters, forming the northern extension of the Vembanad Lake (Kayal), abound in these young and growing Penæid prawns during the greater part of the year and the fishery they support is therefore quite rich and lucrative. Various types of nets like Stake nets, Chinese nets, Drag nets, Cast nets, etc., and ingenious devices like 'Pachil' (Panikkar, 1939; Menon, 1951; Gopinath, 1953; Panikkar and Menon, 1955) are made use of in the capture of prawns; but the stake net catches are comparatively more abundant and may account for a substantial part of the total.

It is difficult at present even to make an approximate estimate of the magnitude of the annual catch due to lack of data. Though we have a fairly good knowledge of the different species of prawns inhabiting these waters from the works of Nataraj (1942), Menon (1954) and Gopinath (1955) their fluctuations in abundance from month to month, size range, growth and other aspects of their bionomics are yet to be fully understood. It was therefore thought that a regular quantitative study of the catches of a couple of stake nets carried out for a fairly long period may serve to reduce the deficiency in this regard to a great extent.

Material and Methods

Two nets were chosen for making these observations. One was located a little to the north of the entrance to the Cochin harbour near the village of Azhikal and the other about 6 to 7 miles south of it, at Thevara (Fig. 1). Between Thevara and the island of Kumbalam to the south of it there is a narrow gap connecting the backwaters with a network of canals passing eastwards for several miles into the interior. These two nets were chosen with a view to ascertain whether and to what extent the catches might differ in two such situations. Easy accessibility, from the point of view of distance, has also received due consideration in their choice.

Observations relating to the weight of the total catch of each of the two nets and the weight of prawns alone were made on alternate days. A random sample of the prawn catch of each net was collected on one day in a fortnight for analysis and study in the laboratory (Fishing is usually carried out only on 8 to 9 days in a fortnight; sometimes the number of days may be less). The sample was first sorted out into the different species composing it and later the weight, number of individuals, etc., in respect of each were determined. The proportion of each species, by weight as well as by numbers

was calculated from the above figures. Total lengths (from the tip of the rostrum to the extremity of the telson) of all individuals of each species in the sample were also usually recorded. When the number was appreciably large on any day only a portion was measured. No effort was made to measure the sexes separately, since on most days a part of the sample consisted invariably of young prawns that could hardly be sorted as males or females. These measurements were subsequently used for drawing length frequency curves for each species from month to month in order to follow, if possible, their growth rates.

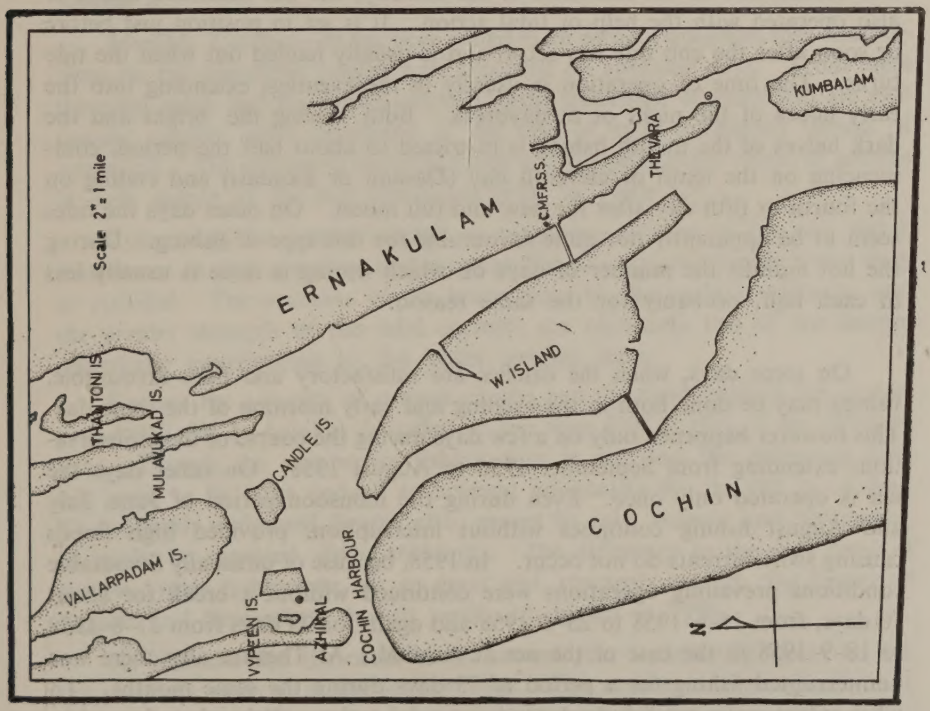

FIG. 1. Showing the location of the two stake nets, at Azhikal and Thevara (indicated by dotted circles).

Description of a Stake Net (Malayalam: *Valu vala, Oonni vala*).—It is a long tapering net, usually about 50′ or a little less in length. The circumference of the mouth may be about 60′. It is usually made of cotton yarn; but the part bordering the mouth is of coir yarn. The mesh size varies in different parts; around the mouth it may be as much as 8″ (from

knot to knot when stretched); immediately behind it is reduced to about $4\frac{1}{2}''$ and still farther back it is progressively $1\frac{1}{2}''$ and $1''$ and at the cod end it is only $\frac{1}{2}''$.* There are 4 coir loops or rings around the mouth for fixing the net to a pair of stakes driven into the bottom mud and the narrow open cod end is tied up with a piece of rope before the net is fixed. When set in position the lower border of the mouth either touches the bottom or remains close to it.

Mode of Operation.—Like the 'Dol' and 'Bokshi' nets of Bombay and similar nets in use elsewhere in the country, the net described above is also operated with the help of tidal action. It is set in position just before or soon after the ebb tide has set in and is usually hauled out when the tide turns. The time of operation is usually in the evenings extending into the early hours of the night or at daybreak. Both during the bright and the dark halves of the month fishing is restricted to about half the period, commencing on the tenth or eleventh day (Dasami or Ekadasi) and ending on the fourth or fifth day after the new and full moon. On other days the tides seem to be apparently not quite favourable for this type of fishing. During the hot months the number of days on which fishing is done is usually less in each half, probably for the same reason.

On some days, when the catches are satisfactory and tides favourable, fishing may be done both in the evening and early morning of the same day. This however happened only on a few days during the course of these observations extending from September 1956 to August 1958. On other days the net is operated only once. Even during the monsoon period of June, July and August fishing continues without interruption, provided high floods causing swift currents do not occur. In 1958, because of unusually favourable conditions prevailing operations were continued without a break for about 70 days, from 15–6–1958 to 23–8–1958 and again for 23 days from 27–8–1958 to 18–9–1958 in the case of the net at Azhikal. At Thevara also there was uninterrupted fishing for a period of 73 days during the same months. To what extent stake net fishing depends on tidal action will be clear from this. When floods and swift currents prevail it is not safe to set the nets in position since the large quantities of floating debris may get entangled in them and they may get torn. It is only under such conditions that stake net fishing is temporarily suspended in the Cochin backwaters.

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* The length, mesh size, etc., are subject to some variation from net to net.

OBSERVATIONS

The data collected can be presented conveniently in two sections. A comparison of the quantities caught by the two nets from month to month, the percentages contributed by the various species and their fluctuations at the two places together with factors influencing the volume of catches, if any, and other relevant observations may form the first section. A brief discussion of some aspects of the biology of these prawns, based on the collected data, may be attempted in the other.

Section I

Monthly Catches.—It has been stated in an earlier paragraph that observations on the quantities caught were recorded on alternate days. From these the total catch and the prawn catch (varying quantities of small fish are also usually caught) were calculated at the end of each fortnightly period of operation. The estimated monthly totals and the percentage values of prawns in each month at the two places are given in Table I.†

Comparing the prawn catches in successive months at the two places it becomes at once apparent that those at Thevara are consistently lower than at Azhikal. The nearness of the latter place to the harbour entrance and the greater strength of the tidal currents are obviously two of the factors apparently contributing to the better catches there.

Further the quantity of prawns caught and the total catch in the second year (1957–58) at Azhikal dwindled to less than half of that of the previous year. Though the number of fishing days is also less the difference does not seem to be large enough to account adequately for the fall in catches. The monthly estimated figures also, except in July, August and September, as might be expected, differ strikingly. The difference in the July catch of the two years is however not so great and, strangely enough, the figures of August and September, though small, are higher in 1958.

At Thevara also the catch in the second year is definitely less; but the fall is not so steep as at the former place. The number of days also follows the same trend. Likewise the catch in July and the succeeding two months in 1958 is higher, thus repeating practically the trend noted at Azhikal.

The average monthly catch at Azhikal in 1956–57 is about 110 kg. In November and December 1956 and January, April, May and June 1957

† In certain months—September, October, December and February—fishing was done both in the evening and early morning at Azhikal. On a few days however there may have been only one fishing and the totals for those months may consequently be slight overestimates. This possibility was accidentally overlooked at the time data were being collected.

TABLE I

Estimated total catches and prawn catches (in Kg.), percentage of the latter and No. of fishing days in each month from November 1956 to October 1958 at the two places

Month	Azhikal				Thevara			
	Total	Prawns	Percentage of Prawns	No. of days	Total	Prawns	Percentage of Prawns	No. of days
1956								
November ..	255·39	189·42	71·3	23	145·15	113·49	78·1	22
December ..	215·00	160·71	74·7	21	89·17	71·39	80·0	20
1957								
January ..	179·94	136·26	75·7	24	73·03	57·00	78·0	17
February ..	140·84	101·28	71·9	20	69·76	61·38	87·9	17
March	154·45	96·30	62·3	21	58·78	46·69	79·4	17
April	197·85	134·49	68·0	23	84·53	64·86	76·7	15
May	265·98	177·22	66·6	23	117·64	86·11	73·2	17
June	199·44	128·77	64·5	22	118·63	84·18	70·9	22
July	149·95	94·16	62·7	23	72·66	53·36	73·4	19
August ..	71·21	35·20	49·4	23	40·19	18·10	45·0	13
September ..	706·55	3·40	0·5	21	87·77	0·34	0·4	6
October ..	202·48	57·6	28·2	19	34·09	27·35	80·2	14
November ..	26·31	10·11	38·4	13	43·66	39·88	91·3	14
December ..	29·25	21·54	73·6	15	5·25	4·57	87·0	7
1958								
January ..	68·19	52·95	77·6	13	22·68	21·91	96·6	10
February ..	50·94	36·42	71·5	17	33·06	28·35	85·7	10
March	79·34	51·81	65·3	19	51·59	33·22	64·4	12
April	49·03	33·13	67·5	13	34·58	29·67	85·8	11
May	139·92	82·63	59·0	22	81·79	68·39	83·6	22
June	95·85	52·07	54·3	25	71·11	48·99	68·8	23
July	139·20	74·52	53·5	31	104·89	67·77	64·6	31
August ..	119·36	58·05	48·6	28	87·40	57·08	65·3	28
September ..	78·07	10·49	13·4	20	16·51	11·83	71·6	12
October ..	87·36	17·51	20·0	15	16·02	14·17	88·4	11
Total for 1956–57 ..	2749·08	1314·28	47·8	263	991·40	684·22	69·0	199
Total for 1957–58 ..	962·82	501·23	52·0	231	568·54	425·86	74·9	191

the estimated figures are markedly higher and these six months may therefore be regarded as probably the best months for prawns. In view of the abnormally low catches of the following year it may not be surpising that in some of these months similar good catches have not been obtained. The landings at Thevara also, on the same basis, were good in the first year.

Proportion of Prawns.—The highest percentage of prawns in the total catch at Azhikal was recorded in January 1958 and was 77·6 and the lowest (0·5) in September 1957. Comparing the monthly figures in the two years (Fig. 2) it would seem that the fluctuations in general follow the same pattern, though the magnitude in any particular month may show considerable disparity as is seen in November.

At Thevara the highest percentage was 96·6 and was recorded in the same month, *viz.*, January 1958. The lowest likewise (0·4) was in September 1957. Despite this similarity, the pattern of monthly fluctuations in the two years, as illustrated by the curves, is quite different. This is particularly true in respect of 1957–58 and will be clear from a glance at Fig. 2. In 1956–57 the trend is approximately similar to that at Azhikal, except in January, February, April and July. If the low catch figures of the second year could be regarded as indicative of an abnormal year the previous year (1956–57) and the data pertaining to that year should, in all probability, reflect approximately the normal condition of the fishery.

It may also be noted here that in both the years, except in 2 or 3 months, the monthly percentage values of prawns is definitely higher at Thevara. This is true in regard to the annual values also.

Factors influencing Catches.—It has been pointed out earlier that the nearness of Azhikal to the harbour mouth and the stronger tidal flow there might probably account for the better catches of that net. For explaining the fluctuations (daily, monthly, etc.) noted at both places other factors like rainfall and the phases of the moon, that are likely to have an influence, may have to be considered.

Rainfall.—Among fishermen and others connected with the prawn fishery the belief is widespread here that rainfall exerts a direct influence on the fishery. This and the recommendation of the Indo-Pacific Fisheries Council (1955) that "it may be necessary to begin collecting data on rainfall and meteorological conditions which may be of significance in determining prawn yields" induced the authors to undertake a comparative study of the catch and rainfall data of the two years. In Fig. 3 the monthly rainfall and catch data are shown separately for the two years. The total rainfall

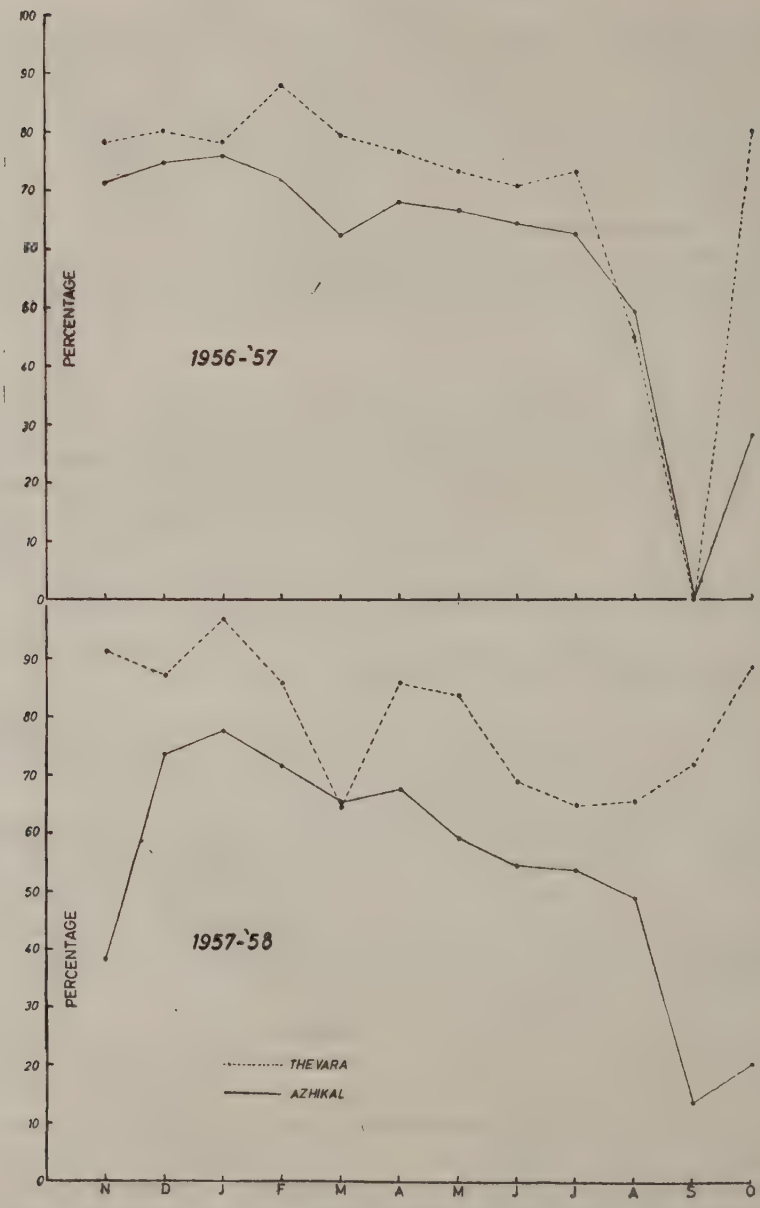

FIG. 2. Percentages by weight of prawns in the total catch at Azhikal and Thevara for the two years 1956–57 and 1957–58.

in 1957 was 3661·7 mm.; in the following year it was much less (2768·0 mm.). If there is any direct relationship between the two the catches of 1957 should be, on the whole, better than those of 1958 and the catch data presented in Table I have definitely shown that they were so.

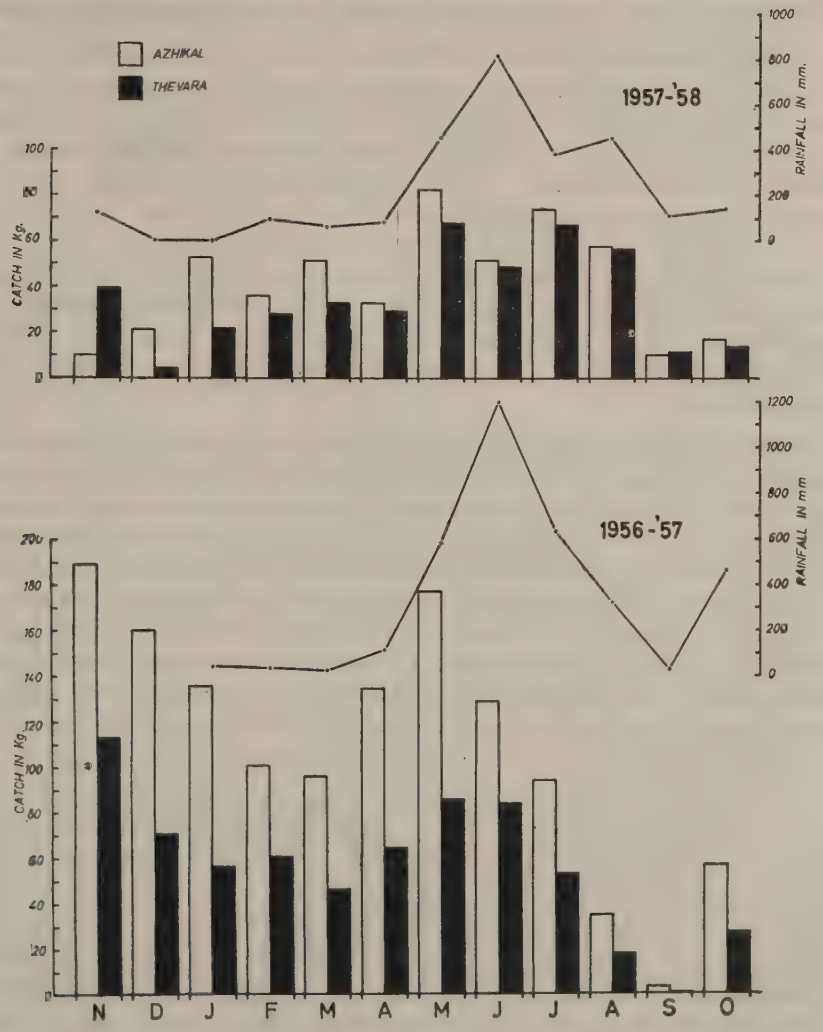

FIG. 3. Monthly prawn catches at the two places in relation to rainfall.

The possibility of the monthly catches also being directly affected by rainfall is indicated by Fig. 3. Since 1957–58 was shown to have been an

abnormal year for the prawn fishery data relating to 1956–57 may be taken up first for examination. From January to March 1956 the catch at Azhikal declined gradually and the rainfall also shows a reduction from 42·0 to 22·0 mm. The catch at Thevara does not fully agree with that of Azhikal since the figure for February is slightly higher than that of the previous month.

During the three months April to June marking the onset of the south-west monsoon the rainfall was increasingly heavier, reaching the maximum of 1196·2 mm. in June. In the first two months of this quarter the landings at both Azhikal and Thevara have steadily improved, the improvement at Azhikal being more marked. In June however there was an abrupt fall there while at Thevara only a slight reduction is noticeable. From July to September both the rainfall and the catches at the two centres came down progressively. The lowest catches were recorded during September and excepting March the rainfall also was least in that month. In October because of a few showers caused by the north-east monsoon the quantity of rainfall registered an increase and the quantity of prawns caught at both centres rose simultaneously.

Except in the month of June the variations in the prawn catches at both centres are thus seen to have followed fairly closely the pattern of variations in rainfall. It is difficult to trace such an agreement between the monthly catch and rainfall in the next year (1957–58). The maximum catch was in May at the two centres and in the next month there is a fall in the catch in this year also. The lowest catch at Azhikal was in September 1958 and at Thevara in December 1957. Rainfall, on the other hand, was least in January 1958 (only a trace). In November 1957 it was 4·8 mm. and in September 1958 about 111 mm. of rain seems to have fallen. In several other months also differences in rainfall and fluctuations in landings seem to bear little or no relationship.

Phases of the Moon.—Examination of the daily catch figures of each fortnight during the two years has revealed that there is some relationship between them and the phases of the moon. The highest catch was usually recorded on the new or full-moon day or a day or two later, but rarely earlier. It is not clear how this happens. Probably the stronger tidal currents on these days may force a larger volume of water through the nets resulting in the capture of a greater number of prawns. Whether their normal movements are influenced and whether the higher catch is partly due to more active movements is a problem on which no evidence has been collected in the course of these observations. It is likely that both causes may have contributed to the improved catches on these days.

Species represented and their Proportion in the Catch.—Nataraj (1942) and Menon (1954) have recorded the species composing the prawn fauna of Travancore and the catches from paddy fields respectively. All or most of them should naturally be expected to be caught from the Cochin backwaters irrespective of the gear used. The following is the list of species observed in the stake net catches arranged under their respective families.

Penæidæ	Palæmonidæ
1. *Penæus indicus*	1. *Palæmon rudis*
2. *P. carinatus*	
3. *P. monodon*	Alpheidæ
4. *Metapenæus monoceros*	1. *Alpheus* sp.
5. *M. dobsoni*	
6. *M. affinis*	
7. *Parapeneopsis stylifera*	

Among the Penæid prawns listed above three species, *viz.*, *P. carinatus*, *P. monodon* and *P. stylifera* have occurred quite irregularly and in insignificant numbers and therefore are of no consequence to the fishery. The position of the two non-Penæid species in the list is also much the same. The fishery therefore is supported, practically entirely, by the 4 species of Penæids, *viz.*, *P. indicus*, *M. monoceros*, *M. dobsoni* and *M. affinis*. The fluctuations in their proportions from month to month at the two places are illustrated in Figs. 4 and 5. Average monthly percentage values for each species at Azhikal and Thevara were calculated based on weight as well as on numbers separately and are set down in Tables II and III. Percentage values based on weight alone may not be enough to provide a correct idea of the proportion of each species when the majority of individuals of a species show large variations in size, from those of another species. For example, the percentage value of *M. dobsoni* by weight in September 1958 was 50·0 at Azhikal while the value by numbers was 81·9 (Table II). It was so because almost one half of the individuals measured only 50 to 60 mm. In the case of the larger species like *P. indicus*, on the other hand, the percentage value by numbers will usually be considerably smaller than that by weight.

Tables II and III and Figs. 4 and 5 make it quite clear that at both centres *M. dobsoni* is the dominant species during the greater part of the year. At Azhikal the highest percentage value for the species was 86·3 (97·8 by Nos.) in the first year (December 1956), and 90·4 (91·3 by Nos.)

in the second year (February 1958). At Thevara the corresponding values were 91·3 (98·5 by Nos.) and 79·7 (92·0 by Nos.) and were recorded in

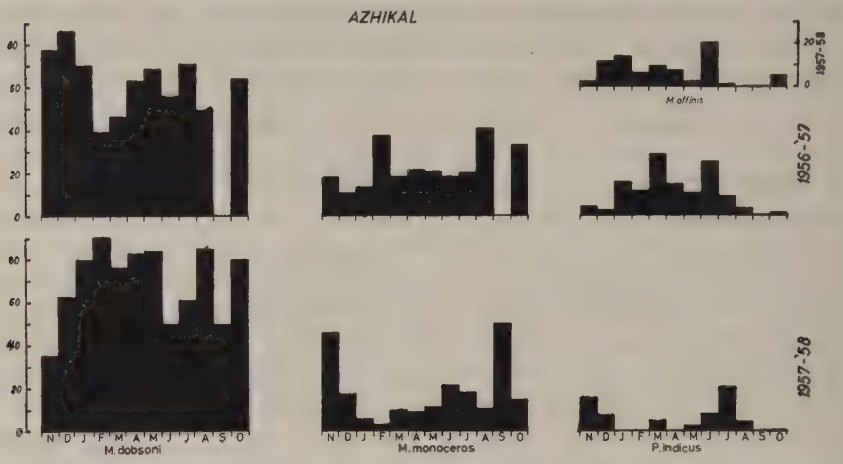

FIG. 4. Monthly variations in percentage by weight of the different species in the total prawn catch at Azhikal.

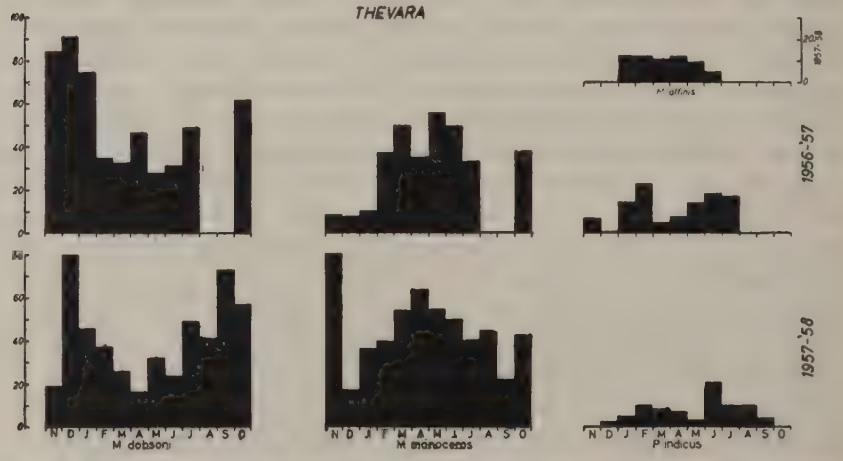

FIG. 5. Monthly variations in percentage by weight of the different species in the total prawn catch at Thevara.

December 1956 and 1957 respectively. The lowest values were 39·5 and 35·6 (59·4 by Nos.) at Azhikal (February 1957 and November 1957) and

TABLE II

Average monthly percentage values of four species of Penæid prawns in the catches at Azhikal from November 1956 to October 1958

Month	*Penæus indicus*		*Metapenæus dobsoni*		*M. monoceros*		*M. affinis*	
	By weight	By numbers	By weight	By numbers	By weight	By numbers	By weight	By numbers
1956								
November	4·3	..	77·5	..	18·2	..	..	..
December	2·5	0·4	86·3	97·8	11·1	1·5	..	..
1957								
January	15·5	0·7	70·3	93·5	13·8	2·1	..	..
February	11·7	..	39·5	..	37·6	..	6·5	..
March	28·5	7·7	46·5	82·8	18·5	7·2	6·2	2·2
April	15·0	2·6	63·3	91·5	21·6	5·7	..	..
May	10·7	2·4	68·4	90·7	20·7	7·0	..	..
June	25·0	7·5	56·2	84·2	18·7	7·2	..	1·0
July	8·8	1·4	70·7	93·5	20·4	5·0	..	..
August	3·1	1·9	49·5	83·8	41·2	11·0	6·2	3·3
September	No data available							
October	1·9	0·2	63·8	92·9	33·2	6·0	1·4	0·9
November	15·6	8·4	35·6	59·4	45·9	21·6	2·7	10·4
December	7·6	1·7	62·8	79·1	17·6	5·3	11·8	13·8
1958								
January	..	0·4	80·0	82·0	5·8	2·2	14·1	14·9
February	..	0·3	90·4	91·3	3·1	1·2	6·4	7·1
March	4·8	1·3	76·2	82·9	9·5	2·8	9·5	12·5
April	..	0·2	82·8	90·7	9·4	2·4	7·6	7·8
May	2·2	0·5	83·9	92·6	11·5	3·8	2·2	2·9
June	8·0	2·3	50·3	66·4	21·5	7·0	20·1	23·9
July	20·4	7·8	60·7	82·9	17·8	6·2	1·0	3·0
August	4·1	1·4	85·1	94·7	10·7	2·5	..	1·3
September	..	0·7	50·0	81·9	50·0	17·4	..	..
October	..	0·1	80·0	87·4	15·0	9·5	5·0	2·9

TABLE III

Average monthly percentage values of four species of Penæid prawns in the catches at Thevara from November 1956 to October 1958

Month	*Penæus indicus*		*Metapenæus dobsoni*		*M. monoceros*		*M. affinis*	
	By weight	By numbers	By weight	By numbers	By weight	By numbers	By weight	By numbers
1956								
November	7·0	2·0	84·3	95·7	8·7	2·2	..	..
December	0·6	0·1	91·3	98·5	8·0	1·3	..	..
1957								
January	14·7	4·6	74·8	92·1	10·5	3·3	..	..
February	22·9	..	35·4	..	37·5	..	4·1	..
March	5·1	3·1	32·9	38·7	50·0	46·1	11·9	11·4
April	7·7	1·2	46·4	68·7	35·8	22·5	10·0	7·5
May	14·1	6·7	28·1	52·2	56·2	37·8	1·5	3·3
June	18·4	6·2	31·7	68·5	49·9	25·2	..	..
July	17·3	4·5	48·9	77·4	33·6	17·7	..	0·2
August	No data available							
September	Do.							
October	..	0·2	61·9	88·5	38·1	10·2	..	0·4
November	..	1·3	19·2	47·3	80·8	50·0	..	0·4
December	2·4	0·8	79·7	92·0	17·8	5·4	..	0·8
1958								
January	5·1	1·7	45·8	62·7	36·5	18·7	12·6	16·7
February	10·0	3·8	37·3	62·4	40·0	17·9	12·6	15·7
March	8·5	4·0	25·9	42·9	54·5	35·0	11·1	18·0
April	7·2	4·0	16·5	30·8	63·9	42·2	12·2	22·8
May	3·4	1·5	32·0	57·7	54·8	20·8	9·7	19·9
June	20·8	15·0	23·9	49·1	50·0	26·0	5·2	9·9
July	10·1	4·0	49·3	72·7	40·5	22·1	..	1·1
August	10·0	6·1	41·6	74·6	45·0	15·4	..	2·8
September	4·1	0·7	73·3	91·3	22·5	7·2	..	0·7
October	..	..	57·2	85·4	42·8	14·3	..	0·2

28·1 (52·2 by Nos.) and 16·5 (30·8 by Nos.) at Thevara (May 1957 and April 1958). It should be noted here that while the highest and lowest values occurred in different months in the two years at Azhikal they were in the same months or in consecutive months at Thevara. Does it imply that the fluctuations in abundance of the constituent species are more regular at the latter centre ?

M. monoceros seems to occupy the second place in respect of comparative abundance. Its highest percentage values were 4·2 (11·0 by Nos.) and 50·0 (17·4 by Nos.) in the first (August 1957) and second years (September 1958) at Azhikal. The lowest were 11·1 (1·5 by Nos.) and 3·1 (1·2 by Nos.) respectively (recorded in December 1956 and February 1958). At Thevara the highest values were 56·2 (37·8 by Nos.) and 80·8 (50·0 by Nos.) and were noted in May 1957 and November 1957. Similarly the lowest were 8·0 (1·3 by Nos.) and 17·8 (5·4 by Nos.) both occurring in December of the two years. Apparently there does not seem to be the same regularity in the occurrence of maximum numbers of *M. monoceros* at Thevara as was noted in respect of *M. dobsoni* though the minimum catch has been in the same month (December) in both years. A glance at Table III, however, would show that in March, April and May the values were uniformly good and over 50·0, going up to 63·9 in April. The apparent irregularity noted above may not therefore be quite so significant as might be assumed.

The third rank from the point of view of abundance is claimed by *P. indicus*. The highest percentage value reached by this species at Azhikal was 28·5 (7·7 by Nos.) and 20·4 (7·8 by Nos.) in March 1957 and July 1958 of the two years. The lowest were in September and October in both years. At Thevara the highest values recorded were 22·9 and 20·8 (15·0 by Nos.) in February 1957 and June 1958 and the lowest in September and October as at Azhikal. It is remarkable that there is a fair degree of agreement in the occurrence of maximum and minimum numbers of this species at the two centres. It should also be noted here that during the course of routine collection of data on catches of *P. indicus* from these backwaters the somewhat sudden scarcity of this species in the months of September and October has been recorded in some years previously. It is not yet clear how this happens.

M. affinis has occurred only in a few months in the first year at both centres. In the second year though it has been recorded in all months the quantities at Thevara were quite small and negligible in almost half of the year.

Section II

It was expected that the regular study of fortnightly samples from the catches at the two centres would yield useful information on some aspects of the bionomics of these species, particularly on growth. Monthly length frequencies in respect of each species were therefore worked out and curves drawn, except when the total number of prawns of any species was less than 25 in any month. A similar attempt made a few years back (Menon, 1954) on material obtained from the paddy field prawn fishery was inconclusive and it seemed therefore worthwhile to repeat it on material obtained direct from backwaters during the whole of the year.

Figure 6 shows the curves relating to *M. dobsoni* and *M. monoceros* for each month of the second year (1957–58). Though the fishery was not so good, data pertaining to that year were chosen because they were available for all the 12 months. A study of these curves is rather disappointing inasmuch as they do not help much in estimating the monthly rate of growth. The modal group from month to month does not show any progressive increase in size. In regard to Azhikal material, for example, the modal group (46–50 mm.) of *M. dobsoni* has remained unchanged for four months, from March to June 1958 and again from August to October (at 56–60 mm.). This peculiarity is equally evident in respect of material obtained from Thevara, where from February to June 1958 the group has remained consistently steady at 41–45 mm.

It is however possible to draw certain general conclusions about their growth in backwaters. In regard to *M. dobsoni* the modal frequency has varied between 41–45 mm. and 56–60 mm. during the course of the year at Azhikal. Between these extremes the groups measuring 46–50 mm. and 51–55 mm. have dominated each for four months. It would therefore seem that a good portion of the post-larvæ entering these backwaters reach these lengths before they return to the sea or get caught in the commercial fishery. At Thevara also the dominant group has varied in length over the same range, *viz.*, 41–45 mm. to 56–60 mm.; but the period of occurrence of any group among them may not be the same as at Azhikal. The largest individuals obtained at Azhikal belong to the 86–90 mm. group and at Thevara to the 81–85 mm. group. This group and in fact individuals measuring over 80 mm. occurred in the Azhikal catches only in the months of September, October and November and their proportion never exceeded 2 to 3 per cent. in any month. At Thevara they were even fewer and occurred only in November. Since growth in the species had been dealt with in

previous papers (1951, 1952 and 1957) little else need be added here on this aspect.

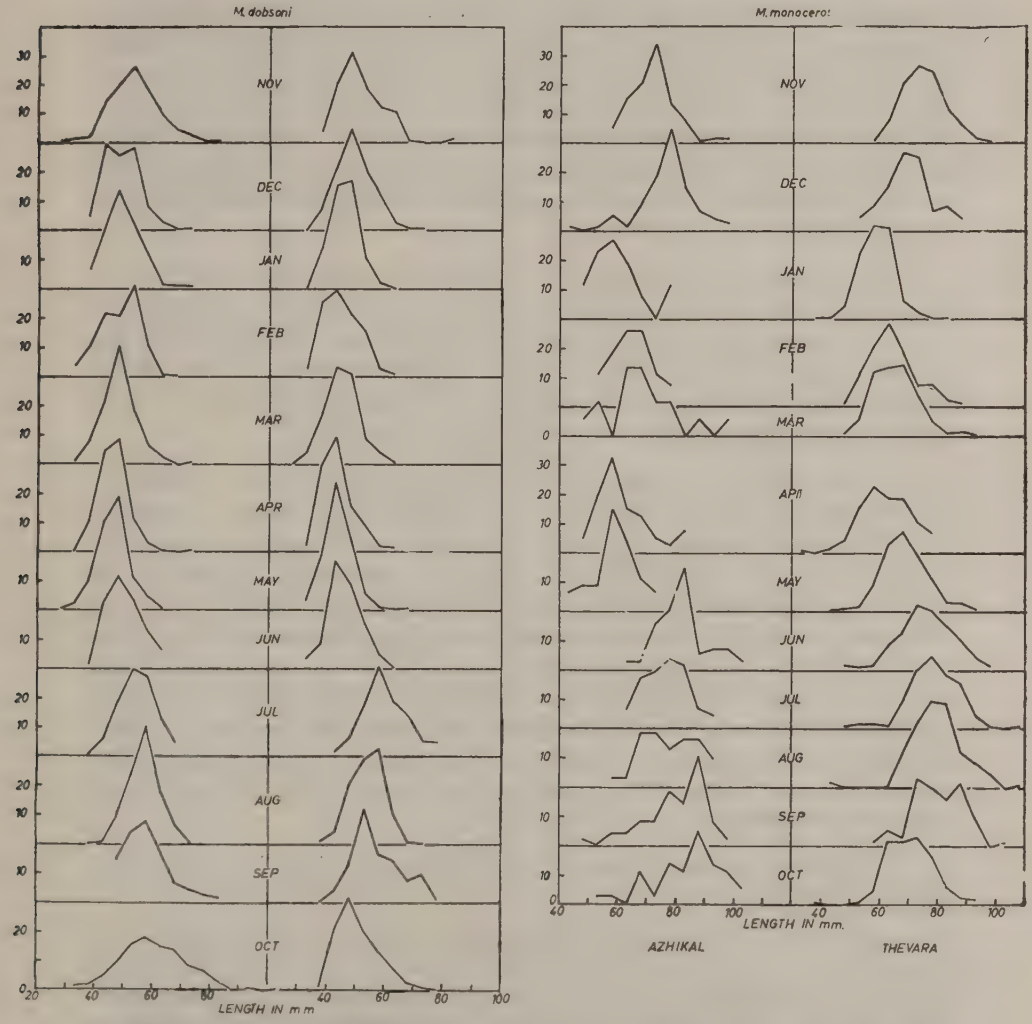

FIG. 6. Length frequencies of the two species in the catches of the two stake nets during November 1957 to October 1958.

M. monoceros.—The modal group in regard to this species has varied in length between 56–60 mm. and 86–90 mm. at Azhikal. The same group has continued to be the dominant group or the next in rank during

successive months in the case of this species also. For example, the 86-90 mm. group dominated in September and October and in the preceding August they stood second in abundance by a small margin. In regard to the catches at Thevara the curves from May to September seem to provide some indication of the monthly rate of growth. The mode in May was at 68 mm. (66–70 mm. group) and it seems to have moved more or less regularly to 88 mm. (86–90 mm. group) in November. The rate of growth among prawns of this species caught in the Thevara net during these months thus seems to be 5 mm. per month. This is in conformity with the observations of George (1960).

The largest group obtained at Azhikal measured 101–105 mm. and was caught only in June and October. They were present in July and the two following months at Thevara. At both centres, however, their proportion is quite small or insignificant. The vast majority of prawns of this species inhabiting these backwaters and connected canals seem to grow only to about 100 mm. or less during their stay in such environments.

Penæus indicus.—Insufficient numbers of prawns in the samples of certain months made it impossible to determine their length frequencies during those months and the series of curves therefore is necessarily incomplete (Fig. 7). It is difficult to draw any conclusions in regard to the rate of growth from their study. The biggest prawns measured come within the group 136 to 140 mm. but it would be clear from a glance at Fig. 7 that the number of individuals measuring over 120 mm. was strikingly few during the six months represented in the figure, even when their total number is reckoned. It would seem that under the conditions prevailing in their brackish-water habitat most of the prawns pass out into the sea or are caught before they are about 100 mm. in length although the adults may reach even double that size.

M. affinis.—The material was not sufficient except in a few months, for length frequency studies.

General Considerations

Effect of Rainfall.—Some of the observations and data presented in the foregoing pages may be briefly considered here in the light of the results of similar work carried out elsewhere. The influence of rainfall on prawn fisheries have been observed by workers in America and Australia. Hildebrand and Gunter (1953) have noted that during dry years the catches of *Penæus setiferus* Linn. in Texas were low and during the intervening wet years they were high. They have computed the correlation coefficient of the catch

in 1937 with the average rainfall for that year and the two preceding years and have shown it to be as high as 0·883. In New South Wales and Queensland, Racek (1959) noticed that ' heavy rainfalls causing extensive river floods ' have the effect in the early stage of inducing all prawn stocks to bury themselves in the mud in estuaries. Later, with the steadily decreasing salinity ' a mass migration of nearly all age groups of various species takes place towards the ocean '. It may be interesting to ascertain if the fluctuations in the catches during the monsoon and immediately after (in the first year) described early could be explained by this peculiar behaviour of prawns.

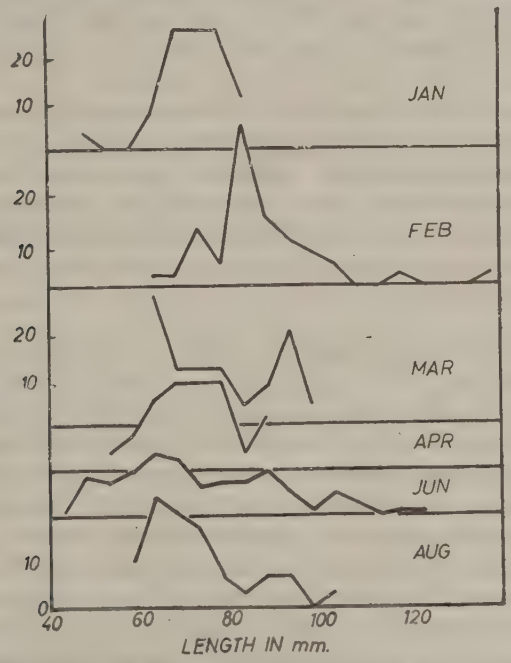

FIG. 7. Length frequencies of *P. indicus* in the Azhikal catches for six months during 1958.

It has been pointed out already that there is evidence for assuming a fairly close connection between rainfall and annual catch. The monthly fluctuations in the catch seem also to be related to the rainfall in the corresponding months in most months in the first year. Such a relationship however is not very much in evidence in the second year. The correlation coefficient of catch with amount of rainfall for the year 1957 has been calculated and the values are 0·54 for Thevara and 0·35 for Azhikal. (The figures, particularly that for Azhikal, are lower than what might be expected from the graph.)

In respect of monthly catch in the first year that of June is noteworthy since it is much less at Azhikal (slightly less at Thevara) than that of May although the rainfall was more than double the amount. It would seem therefore that the first few showers of the south-west monsoon usually falling in May stimulate an active seaward movement, resulting in a sharp rise in the prawn catch. In subsequent months the catch steadily falls along with decreasing rainfall up to September though the salinity may also be simultaneously declining (George, 1958). In the second year also the same relationship between catch and rainfall exists in May and June. In July of that year, however, though the rainfall is less than half of that of the previous month the catches showed marked improvement. In the next two months they declined somewhat precipitously in September as at Azhikal. The improvement noted in the catch of July may probably be accounted for by the mass migration accompanying decrease in salinity observed by Racek (*op. cit.*) in Australian estuaries. It did not happen in 1956–57, though for reasons explained elsewhere, that year should be considered to reflect the normal conditions of rainfall and fishery. Presumably factors other than rain and salinity not yet understood may also be exercising some influence on their movements.

Lunar Periodicity.—The highest catch, as stated before, was usually recorded on the new or full-moon day or on either of the next two days. The possibility that this might be caused by the stronger tidal currents prevailing on those days and the more active movements of prawns under lunar influence has also been hinted at. According to Racek (*op. cit.*) there is pronounced lunar periodicity on the behaviour, abundance, moulting, breeding and offshore spawning runs of Penæid prawns. Wheeler (1937, quoted by Racek) has come to the conclusion that ' the effect of moonlight is one of the most likely factors controlling this periodicity ' in respect of abundance and schooling of some decapods including Penæids. Racek, however, is inclined to discount the direct inhibitory effect of moonlight in causing lunar periodicity among predominantly demersal commercial species of Penæid prawns.

Such a sharply defined lunar periodicity, regardless of the factors responsible for it, has been described by him in respect of the seaward migration of two important commercial species of New South Wales, *viz.*, *Metapenæus macleayi* (Haswell) and *Penæus plebijus* Hess. This ' spawning run ' takes place in ' the earlier part of the outrunning tide chiefly at night ' during the summer months December to March. Starting 3 to 5 nights after full-moon the peak of this activity was reached on the 12th night in the case of

M. macleayi and the 16th night in the case of the other species. It stopped on the 19th and 21st day respectively after the full-moon.

Since the stake net catches studied here were obtained in all the 12 months of the year (the quantities showing wide variations) it is not clear if they are always the result of spawning runs similar to those of the Australian species. In the case of non-migratory species like *M. mastersii* (Haswell) periodicity in abundance has been observed, larger schools occurring near the new-moon days. Migratory species also are reported to behave in this way, the behaviour being quite pronounced in estuaries. Since the species dealt with here are migratory, changes in abundance produced in the same way might partly account for the catches.

Lunar periodicity, as observed in the Australian species, occurred usually in the darker half of the month, the peak having been noticed shortly before or after the new-moon. Little difference has been noticed in the quantities caught by stake nets during the brighter and darker fortnights from the Cochin backwaters and it would seem therefore that the factors responsible for the movements of prawns are in operation during both. Could Lunar periodicity account for their abundance and movements in the brighter half of the month? Until planned observations are carried out here no definite opinion can be ventured in answer to this question. Variations in the strength of the tidal flow therefore seem to be the only probable factor, the influence of which is clearly seen on the stake net prawn catches.

In the course of some experiments with three species of prawns Racek (*op. cit.*) has reported that each species was found to be active, *i.e.*, swimming or crawling, at about the same part of the day and the different species varied considerably in regard to the time and duration of this activity. This behaviour is said to be quite independent of light. It may be rash to base any inference on this, since prawns living in their natural environments may show an altogether different pattern of behaviour. But the author is inclined to assume that light is not a factor causing periodicity and the catch data presented in this paper seem to be in agreement with this view.

Growth.—The attempt to estimate monthly growth by the method of length frequency analysis has not proved quite satisfactory since it has failed to give any definite results. It is true that the curves (Fig. 6) from May to September relating to material from Thevara seem to indicate a monthly rate of 5 mm. for *M. monoceros*. The curves for the rest of the months and those relating to material from Azhikal do not, however, give any support to this conclusion. Some of them are peculiar since the modes

remain unchanged during a number of months in succession. It has already been stated that vast numbers of post-larvæ enter the backwaters during a fairly long period extending over several months. They seem to grow rapidly and take the place of the modal groups as fast as the latter are removed by fishing. This might also account for the abrupt fall in the length of the modal group in some months.

In the case of *M. dobsoni* (Menon, 1951 and 1955) and *Parapeneopsis stylifera* (Menon, 1953) it was possible to deduce the annual growth and the probable duration of life by this method. Kubo (1956) has summarised the results of similar studies on a number of Japanese species of Penæid and Palæmonid prawns. In respect of *M. monoceros* it appears that a carapace length of 27 to 34 mm. (female) and 21·5 to 25·5 mm. (male) is reached by the end of the first year. Since the total lengths corresponding to these carapace lengths are not given in the summary it is not possible to compare them with the maximum length recorded in the stake net catches, which might also, in all probability, be the result of an year's growth.

Summary

1. Observations made on the catches of two stake nets from the Cochin backwaters, one located at Azhikal close to the entrace to the Cochin Harbour and the other six to seven miles south of it at Thevara during the period November 1956 to October 1958 are discussed in the paper.

2. The total catch, prawn catch and its percentage have been determined for each month during the period of observation.

3. The fluctuations in the prawn catch have been studied and their correlation with rainfall, strength of tidal flow and other factors discussed.

4. The species of prawns composing the catches, as revealed by regular analysis of fortnightly samples from both centres, have been listed, and the quantitative variations from month to month exhibited by the four important Penæids, *viz.*, *P. indicus*, *M. dobsoni*, *M. monoceros* and *M. affinis* have been described.

5. Monthly length frequencies have been worked out and curves drawn in respect of the first three species in order to estimate their monthly rates of growth, if possible. But no definite results were obtained.

Acknowledgment

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preliminary analysis and measurements and the authors would like to thank them for it.

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SPAWNING FREQUENCIES AND BREEDING SEASONS OF SOME FRESHWATER FISHES WITH SPECIAL REFERENCE TO THOSE OCCURRING IN THE PLAINS OF NORTHERN INDIA

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Introduction

It is well known that the differences in the spawning behaviour of teleosts can to a certain extent be illustrated on the basis of the condition revealed by the unspawned eggs in the ovary (Heidrich, 1925; Clark, 1925, 1934; Hickling and Rutenberg, 1936). Many studies on the ova diameter frequencies have been undertaken during recent years and in almost all cases it has been accepted that species which have all the ovarian eggs of similar size spawn them together whereas those which have a wide range in oocyte sizes may have several groups of eggs matured and shed periodically during the breeding season (De Jong, 1939; Prabhu, 1956 and Dharmamba, 1959). Qasim (1956 *a* and 1956 *b*) made similar studies on two marine fishes *Blennius pholis* L. and *Centronotus gunnellus* (L.) and confirmed his results on the frequency of spawning by an observation in the aquarium. He showed that the common British blenny, *B. pholis* which has multiple batches of oocytes spawns three times during the breeding season, whereas the other shore fish of the British Isles, *C. gunnellus* has a single stock of eggs and spawns once only. Such differences in the spawning habit of marine teleosts living in temperate regions are correlated with their geographical distributions (Qasim, 1956 *a*). Single stock of oocytes in the maturing ovary is a peculiarity of the arctic-boreal species which spawn only once a year, their spawning seasons being short and occurring during winter and early spring. Multiple batches of eggs, on the other hand, are found among the mediterranean-boreal forms which produce several broods annually, their spawning seasons being long and occurring during spring and summer (Qasim, 1956 *a*).

Among Indian forms, studies on the size frequency distribution of oocytes have been undertaken on marine and estuarine fishes only (Karandikar and Palekar, 1950; Palekar and Karandikar, 1952; Prabhu, 1956; Dharmamba, 1959). There has been no previous account on any of the freshwater fishes,

The present paper deals with the spawning frequencies and breeding seasons of various species in the inland waters of Aligarh and other neighbouring areas.

Material and Methods

Table I gives the various species taken during the present investigation. In all, nineteen different species were studied which include carps, catfishes, murrels, grey mullet and spiny eel. To establish the breeding season of each species, observations were made on its gonad condition according to an arbitrary scheme (*see* below) over a greater part of the year. Ripening or ripe ovaries were then taken from the main breeding months, cut into small portions and fixed in Bouin's fluid. On hardening, they were opened in glass dishes and the oocytes carefully separated from the adhering tissues. All the oocytes thus obtained were measured under a micrometer eye-piece. In making measurements, the small yolkless cells which were much more numerous than the oocytes and apparently belonged to the immature class were omitted. In those species where the ovary was very large, only a portion was taken for the oocyte measurements. Generally three to four average sized individuals of each species were selected for the oocyte study and from these fishes a typical condition was laid down on the basis of its predominance to illustrate the distribution of oocytes in that species. In each individual roughly 500 to 1,000 eggs were measured indiscriminately.

Gonad Condition and Nature of Oocytes in Maturing Ovary

The degree of maturity of gonads in various species was determined according to the arbitrary scheme used for *B. pholis* and *C. gunnellus* (Qasim, 1957 *a* and *b*). In all, five maturity stages were defined as follows:—

(1) Immature virgins	Ovaries thin and ribbon-like, eggs microscopic
(2) Maturing virgins or recovered spents	Ovaries swollen and containing eggs just visible to the naked eye
(3) Ripening	Ovaries enlarged and containing conspicuous opaque eggs
(4) Ripe	Ovaries distended and containing large translucent eggs
(5) Spent	Ovaries collapsed with no eggs seen by the naked eye. In some cases a few residual eggs present

TABLE I

Duration of spawning in various freshwater fishes as deduced by the occurrence of ripe and spent stages in various months, Riverine locality includes the rivers Ganga, Jamuna and Kali. Fishes captured from Naujheel, a large lake about 30 miles away from Aligarh have been kept as riverine, for this lake gets connected with the river Jamuna during monsoon months*

	Species	Locality	Probable duration of breeding	Time of maximum spawning
Carps	*Cirrhina mrigala* (Ham.) ..	Rivers	July-August	August
	Labeo rohita (Ham.) ..	Rivers	July-August	August
	Labeo calbasu (Ham.) ..	Rivers	July-August	August
	Barbus sarana (Ham.)† ..	Rivers	Late June to early September	July and August
	Chela bacaila (Ham.)† ..	Ponds	June-September	August
	Barbus stigma (Cuv. and Val.)	Ponds	June-September	August
	Barbus (Tor) putitora (Ham.)	Rivers	Non-seasonal	Over a greater part of the year
Cat-fishes	*Wallagonia attu* (Bloch) ..	Rivers	June-September	July and August
	Eutropiichthys vacha (Ham.)	Rivers	June-September	July and August

	Callichrous pabda (Ham.) ..	Rivers	June-September	July and August
	Bagarius bagarius (Ham.)† ..	Rivers	June-September	July and August
	Mystus vittatus (Bloch) ..	Ponds	June-September	July and August
	Mystus cavasius (Ham.)† ..	Ponds	June-September	July and August
	Heteropneustes fossilis (Bloch)	Ponds	Late July-October	August and September
Murrels	*Ophicephalus striatus* Bloch	Rivers	June-October	July and August
	Ophicephalus marulius Ham.	Rivers	June-October	July and August
	Ophicephalus punctatus Bloch	Ponds	June-September	July and August
Grey mullet and	*Mugil corsula* Ham. ..	Rivers	July-September	July and August
Spiny eel	*Rhynchobdella aculeata* Bloch	Ponds	July-September	August

* A small perennial river of the Western U.P. † Data based on small numbers.

It can be seen from Table I that the material which formed the basis of this study came from two different localities, rivers and ponds. In riverine forms, the occurrence of various stages of maturity was noted in specimens obtained from the local fish market. Depending upon the availability of each species, it became only possible to make observations for a definite period of the year, generally two months before the onset of monsoons (April and May), three months during the monsoons (June to August) and three months after the monsoons (September to November). Pond fishes, on the other hand, were collected by the authors themselves with the help of the technical staff of the department. They were thus made available in large numbers throughout the year and were used for more intensive studies on their biology. Complete data on breeding and its related aspects of various pond fishes will be dealt under separate communications. For the present work, to make comparison more uniform in all the species, the data on the seasonal changes in gonads are given in the form of time and duration of breeding seasons (Table I), as deduced by the occurrence of ripe and spent stages in various months.

Ripening and ripe ovaries of fishes contained oocytes of several different kinds. Those fishes which contained a single group of oocytes, free, large, ripe ova formed the main bulk. The other type present was that of small yolkless cells which were generally embedded in the tissues and probably included follicle cells and oogonia. Other species which possessed multiple groups of eggs, the oocytes were at various stages of development. In addition to the immature yolkless cells, there were also maturing ova which could be distinguished as small opaque eggs provided with little yolk; free mature ova, well supplied with yolk and large translucent ripe ova, full of yolk. Prabhu (1956) made similar observations on the oocytes of maturing ovaries of marine and estuarine fishes.

Spawning Frequencies

Carps.—Size frequency distributions of oocytes in all the species of carps studied are given as histograms in Fig. 1. In each species the month to which the data refer has also been indicated in the figure. As can be seen from the figure, in the four riverine forms, namely, *Labeo rohita*, *Labeo calbasu*, *Cirrhina mrigala* and *Barbus sarana*, conditions shown by the ovaries are very similar. All these species possess a single group of large oocytes evidently destined to be spawned in a single spawning act. The time and duration of spawning in all these species are practically the same, the breeding seasons last for about two months during the monsoons, July and August (Table I). In the Punjab area a large number of riverine carps has been

reported earlier to spawn during the monsoons, main breeding months being July and August (Khan, 1924 and 1942). A short spawning season, as is shown by these fishes, seems a characteristic feature of all those species which possess a single group of oocytes (Qasim, 1956 *a*).

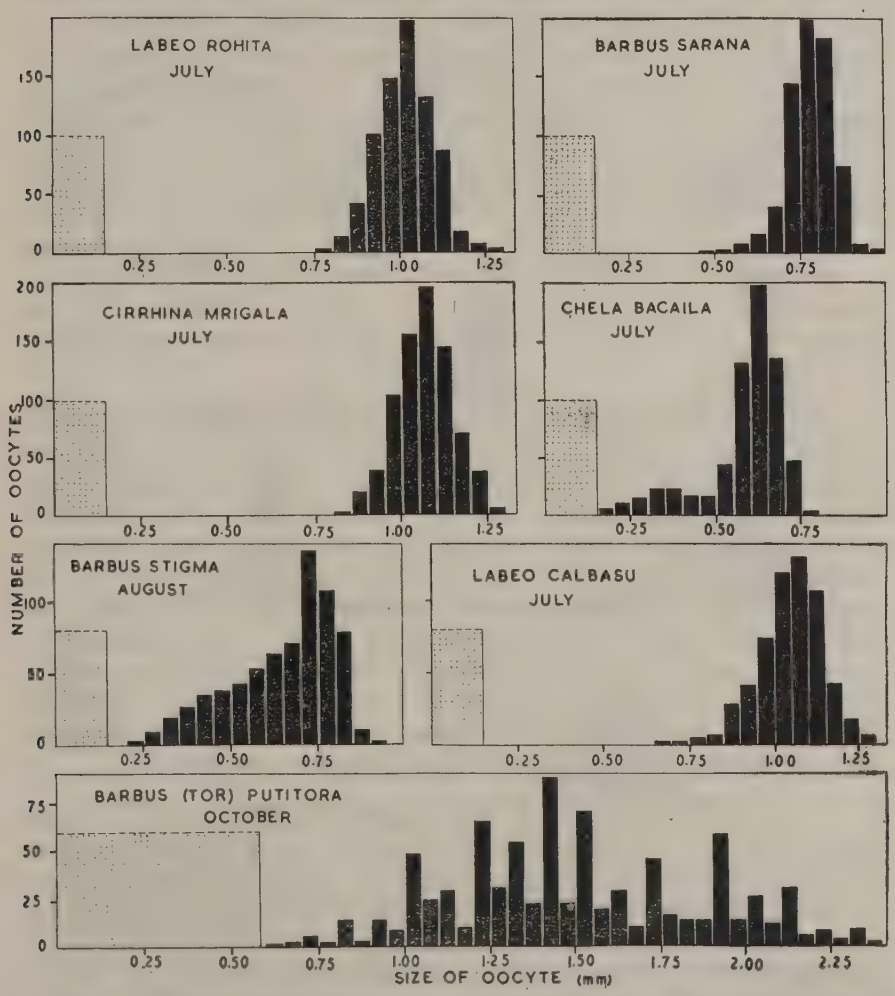

FIG. 1. Histograms showing size frequency distributions of oocytes in maturing ovaries of carps. The various months when typical conditions occur have been indicated with each species. Maturing ova likely to be spawned during the current breeding season are shown as black histograms. The much more numerous yolkless cells which remain in the ovary are marked by stippling. These are either absorbed in the body or form next season's brood.

The conditions shown by the ovaries of other two carps, *Barbus stigma* and *Chela bacaila* collected from ponds are slightly different (Fig. 1). In these species though the size range of the oocytes is large yet there is no clear differentiation of more than one batch of oocytes to be spawned during the same breeding season. Presumably the small oocytes remain in the ovary and are finally absorbed in the body, a feature well known in freshwater fishes. The breeding season in these two carps is comparatively longer and lasts for about four months, June–September. A prolonged breeding in these fishes, as one might infer, is not due to a succession of spawnings in each individual. On the other hand, in ponds, the population of each species is broken up into distinct and separate units; and since the ecological conditions vary from pond to pond, the breeding in all these units does not get synchronised. In some ponds, there may be a continued appearance of gravid fishes whereas in others spent stage may predominate. It is impossible to distinguish these two categories of fishes objectively, so it was thought best to present an overall picture of breeding season from ponds in general.

The ovary of *Barbus* (*Tor*) *putitora* shows an entirely different condition (Fig. 1). In this species the size range is large and there is a continuous gradation from the smallest to the largest size groups indicating several batches of eggs at all stages of maturity. On the basis of this peculiarity it could be generalized that in *Barbus* (*Tor*) *putitora*, the production and withdrawal of eggs from the ovary is a continuous process and that the species may spawn several times over a greater part of the year. The gonads with advanced stages of maturity (Stages III and IV) are seen throughout winter and summer. Earlier authors give three breeding seasons of the mahseer (i) January and February, (ii) May and June, (iii) July to September (Khan, 1940; Macdonald, 1948). These findings fall in close agreement with our deduction on the basis of its ova diameter measurements.

Cat-fishes.—Figure 2 gives the size frequency distributions of the oocytes in all the species of cat-fishes studied. A comparison of various histograms in the figure would reveal that all cat-fishes have spawning frequencies similar to those of the first four species of carps noted above. The entire annual egg production in these cat-fishes seems to have been concentrated into a single spawning act. There are only two types of eggs present in their ovaries, the immature and the ripe and that in most cases, the former is widely separated from the latter. Earlier, studies on *Mystus vittatus* of the brackish-waters (estuarine) have revealed similar conditions of the ovary (Prabhu, 1956).

The five species, namely, *Wallagonia attu*, *Eutropiichthys vacha*, *Bagarius bagarius* and *Callichrous pabda* which came from rivers had their ovaries predominantly ripe from May to July. In August gravid fishes became less numerous. It can therefore be inferred that June, July and August are the main spawning months. A single batch of eggs present in the ovary provides

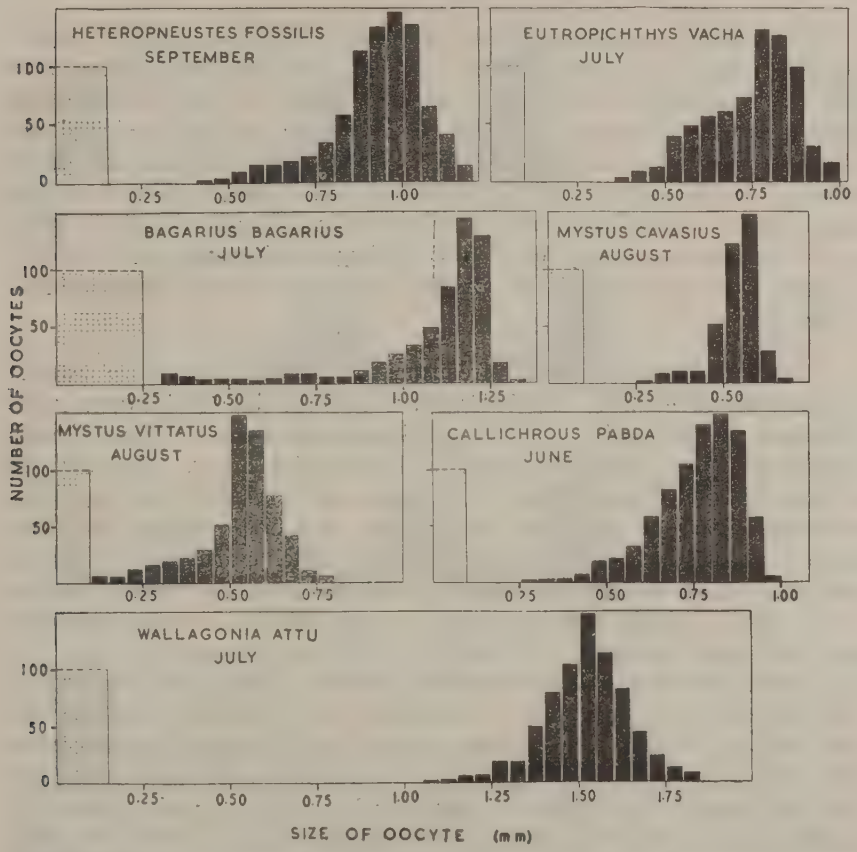

FIG. 2. Histograms showing size frequency distributions of oocytes in maturing ovaries of cat-fishes. Otherwise as in Fig. 1.

a strong evidence that each individual spawns once only during the season. Previous authors have also observed the spawning of *Wallagonia attu* in July (Ahmad, 1944 and Mookerjee *et al.*, 1944).

The other three cat-fishes (*Mystus vittatus*, *M. cavasius* and *Heteropneustes fossilis*) collected from ponds showed similar conditions of the

oocytes. In all probability there are single batches of eggs in these species. The spawning seasons, however, in these species seem longer than the riverine cat-fishes (Table I). As noted earlier in carps, presumably in cat-fishes too, due to varying conditions of food and shelter prevailing in different ponds, there occurs in some ponds either a delayed spawning or its total inhibition. In the latter case the entire egg mass is absorbed in the body.

In *H. fossilis*, according to Ghosh and Kar (1952) that there is a regular seasonal cycle in the gonads, it appears that each individual spawns once only. A gradual fall in the gonad weight as shown by these authors seems quite suggestive. Perhaps the small-sized eggs are not spawned and are gradually absorbed in the body. At Calcutta the period of maximum gonad activity in female as shown by Ghosh and Kar (1952) lasts from April to July. According to our findings that the individuals at Aligarh with ripe ovaries are not uncommon during the months of August, September and October, it appears that spawning in *H. fossilis* occurs late in the northern India (Table I).

Murrels.—The ova diameter frequencies of the following three species: (i) *Ophicephalus marulius*, (ii) *Ophicephalus striatus*, (iii) *Ophicephalus punctatus* have been shown in Fig. 3. In all these species there is a clear evidence of more than one batch of oocytes in the maturing ovary. Generally the average-sized individuals contain two groups and it is most likely that their withdrawal from the ovary may involve more than one spawning act. This behaviour of producing a succession of broods by each individual is in marked contrast to those of carps and cat-fishes which have a single batch of oocytes and produce a single brood annually. In murrels the breeding season is long and lasts throughout the monsoon and post-monsoon months. All through this period gravid fishes are very common. The cycle of maturation and depletion of gonads in the well-known pond murrel *O. punctatus* has been studied in detail. Its breeding season lasts from June to September. The young fishes guarded by both sexes are of common occurrence throughout the rainy season. At Madras, *O. punctatus* has been reported to have two breeding seasons corresponding to two monsoon rains of the south (Raj, 1916). According to Khan (1924) the breeding season of *O. marulius* in the Punjab lasts from April to July. In *O. striatus*, Raj (1916) gives two breeding seasons at Madras, January to February and June to July. The same species in the extreme south of India has been observed to breed throughout the year (Alikunhi, 1953). It is interesting to note that *O. striatus* which has a definite breeding season in the northern India breeds non-seasonally in the south. Presumably moderate climate and abundant rain-

fall of the south provide favourable conditions for breeding throughout the year. In the north such conditions are only prevalent for a limited period during the monsoon and post-monsoon months. Each individual, therefore, spawns repeatedly during these months.

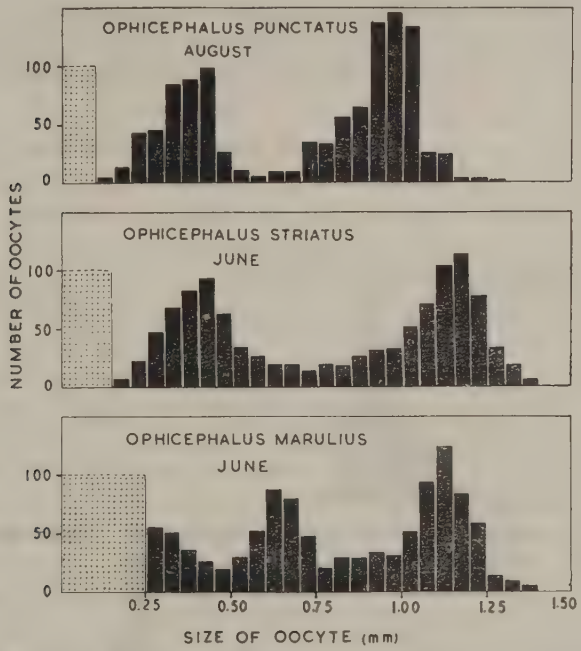

FIG. 3. Histograms showing size frequency distributions of oocytes in maturing ovaries of murrels. Otherwise as in Fig. 1.

Grey Mullet and Spiny Eel.—The conditions revealed by the ovaries of *Mugil corsula* and *Rhyncobdella aculeata* are given in Fig. 4. Both these species contain a single group of oocytes and spawn once a year, their spawning seasons being short and occurring mainly during July and August. Previous authors give the breeding season of *M. corsula* as July and August at the Contai coast, West Bengal (Pillay, 1949), June and July at Barrackpore (Pakrasi and Alikunhi, 1952). In other species of mullets, studies on the ova diameter measurements have revealed interesting conditions. *Mugil cunnesius* Valenciennes, a marine and estuarine form contains a single group of oocytes. It breeds from May to August (Sarojini, 1958). In *M. parsia* H. another marine form, there are two batches of eggs and its

spawning season at Calcutta lasts from December to March (Sarojini, 1957).

Breeding of Fishes in Relation to Seasons

The breeding behaviour of all the species discussed above suggests a principle which may be applicable to all freshwater fishes living in the plains of northern India. On the basis of their ova diameter frequencies, the various species can be divided into the following three categories:—

Category I

In this category are included all those species which possess a single batch of maturing eggs in their ovaries. The spawning in these fishes is adapted to an annual rhythm. The cycle of maturation and depletion of gonads

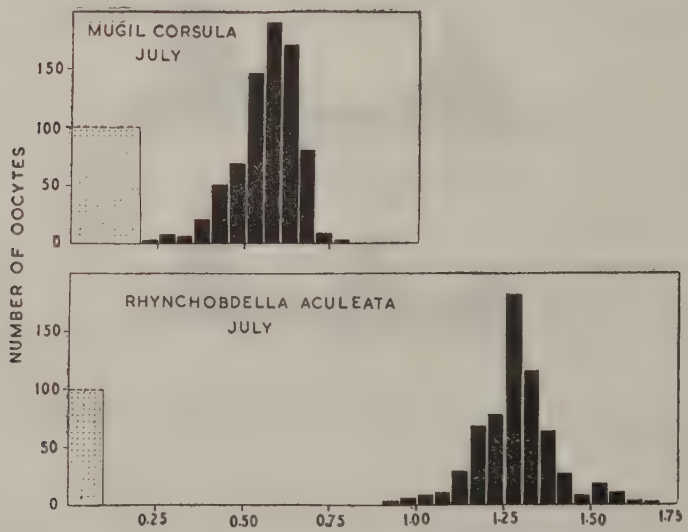

Fig. 4. Histograms showing size frequency distributions of oocytes in maturing ovaries of grey mullet and spiny eel. Otherwise as in Fig. 1.

occurs only once a year and synchronises throughout the population with the onset of monsoon rains. In all such forms, the gonads show a regular seasonal change, and at any given time, the state of maturity is uniform almost in all individuals of the population. An outline of such a regular seasonal change in the gonad condition is presented diagrammatically in Fig. 5 (*a*). The main features of the breeding cycle can be explained as follows:—

From November to January all fishes likely to spawn during the forthcoming breeding season reach the maturing stage. This stage is followed by the ripening stage during February, March and April. In May and June the fishes are predominantly ripe but in July spent fishes begin to appear and their proportions increase rapidly in subsequent months.

In some species, and more particularly among cat-fishes, the breeding cycle showed slight variations from the general picture presented above. This was mainly caused by the adolescent groups. These fishes maturing for the first time are late-spawners and therefore, reach peak ripeness towards the end of the breeding season.

Category II

This category includes fishes which have more than one group of maturing oocytes. In such forms, owing to a succession of spawnings, the breeding cycle of each individual takes an independent course. The breeding season is long and the stages of maturity at any given time show a considerable overlap in the population. A diagrammatic representation of such a breeding cycle is given in Fig. 5 (*b*). As can be seen from the figure, at no time of the year there is an exclusive preponderance of one stage of maturity. In October and November when the majority of fishes are spent, a small portion begins to show maturing condition of the ovary. In December there is a rapid increase in the maturing stage and in January some fishes reach the ripening stage. In February the proportion of ripening stage increases appreciably and in March ripe fishes begin to appear. From then onwards due to repeated spawnings both ripe and ripening stages occur until August. During these months as the gonads do not become spent after early spawnings, there is a general absence of the spent stage. In all these forms the breeding season seems so adjusted that its commencement falls with the onset of pre-monsoon showers. Conditions for breeding seem to remain favourable for a much longer period as the fishes continue to breed in post-monsoon months also. It seems that in the plains of northern India the seasonal rhythm in breeding is imposed on these fishes as a result of extreme and harder weather conditions which prevail during the corresponding winter and summer, for species, like *O. striatus* which breeds seasonally in this part of the country, has a non-seasonal breeding in the south.

Category III

All those species which have oocytes of all sizes ranging from the smallest to the largest with no well-marked batches, *e.g.*, *Barbus* (*Tor*) *putitora*

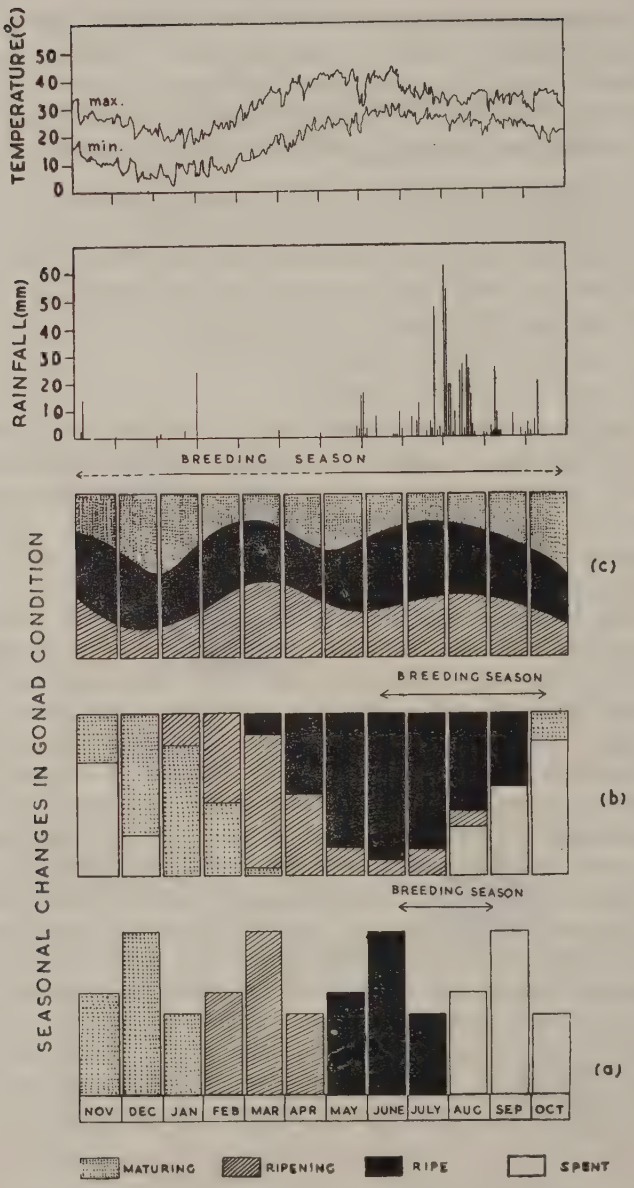

FIG. 5. The relation between breeding seasons, rainfall and atmospheric temperature. (*a*), (*b*) and (*c*) show arbitrary representations of the cycles of maturation and depletion of gonads in the population of various species categorised on the basis of their ova diameter frequencies. (*a*) Regular seasonal cycle when in each individual the withdrawal of all mature ova occurs in a single spawning (category I). (*b*) Overlapping seasonal cycle when each individual has a succession of spawnings (category II). (*c*) Non-seasonal breeding when each individual has an independent breeding rhythm (category III). The rainfall and temperature data refer to Aligarh for the year 1959.

could be included in this category. A general picture of the breeding cycle in such species is given in Fig. 5 (*c*). It is evident from the figure that there is no seasonal rhythm in breeding. Since the cycle of maturation and spawning becomes a continuous process, the population at all times has a random selection of all stages of maturity. The degree of their preponderance may vary according to the frequency of spawning. If conditions of temperature and food supply are favourable, there is no likelihood of coming across spent gonads in the population. On the other hand, if conditions for the building up of reserves are not optimum, there may be a temporary cessation in the gonad activity and this may be reflected by slightly shrunken and quiescent gonads at some stage.

Use of Maturity Stages as an Index of Spawning

It seems important to point out that various arbitrary classifications of gonad conditions or maturity stages devised to establish the time and duration of breeding in fishes can apply successfully only to those forms which show a regular seasonal change (Category I). These classifications with certain modifications and care can also be used to illustrate the spawning seasons of those fishes which produce more than one brood annually provided that their cycles of spawning are extended over one or at the most two definite periods (Category II). In fishes where there is a non-seasonal breeding, all stages of maturity occur practically throughout the year (Category III) and a study of gonads if used to provide an index of spawning is likely to give misleading results. As an example, a fish which has attained peak maturity will be taken as ripe. After it has spawned once, the condition of the gonad instead of moving towards the spent stage to indicate spawning, will go backwards and most probably will be identified as a ripening stage. Perhaps it would be even more difficult to assign a correct maturity stage to those individuals which have spawned more than once.

Breeding Seasons in Relation to Rainfall and Temperature

Many possible factors have been suggested by earlier workers as influencing the spawning of freshwater fishes. In major carps it has been established that intensive flooding either caused by the rainfall or by artificial means, capable of inundating shallow areas, are essential to induce spawning (Hora, 1945). High oxygen content and pH of water are the other factors on which considerable emphasis has been laid (Mookerjee, 1945; Mazumdar, 1945). According to Ganapati, Alikunhi and Thivy (1951), an access to suitable spawning ground was more important to induce spawning than the

physico-chemical condition of water. Since the spawning of many fresh-water fishes occurred in shallow areas, such grounds could only be made available either by flooding or by a general decrease in the water level during a period of drought (Alikunhi and Rao, 1951). Recent observations on the breeding of major carps at a fish farm in the Punjab seem to confirm the view that the chemical composition of water played no role in the spawning and that the spawning was mainly induced by the flood-water having a current of moderate intensity (Khanna, 1958).

The other factor which has been found to affect the spawning of fishes is the temperature. Many instances of optimum temperature conditions as a prerequisite for spawning have been reported earlier (Khan, 1945; Das and Das Gupta, 1945; Smith, 1945) and the temperature range at which the major carps have been observed to breed seems 75 to 86° F. (Hora, 1945).

In the present investigation an approach towards the relationship between physical factors and spawning can be made if the cycles of maturation and depletion of gonads as shown by the various categories of fishes are compared with the seasonal rainfall and temperature (Fig. 5). The evidences can be summarized as follows:—

1. Breeding in most fishes seems directly related to the monsoon cycle; and since in the plains of northern India, the outbreak of monsoon is usually late, the spawning is also delayed accordingly in latitudes further north.

The report of the Meteorological Department based on a ten-year survey of monthly rainfall frequencies throughout India shows that Delhi has on an average 28 inches of rainfall spread over a period of 52 days in a year (*The Statesman*, Monday, June 6, 1960). Roughly the same data apply to Aligarh and other areas of the western U.P. Of the other major cities of India, the report says, "Calcutta with an average rainfall of 63·2 inches has 242 rainless days per year and Bombay whose average rainfall is 75·1 inches has 257 rainless days. The number of rainless days in Madras was 270 while the average rainfall was 44 inches. Except south India, July is easily the wettest month, although in some places there is more rain in June or August than July. For Madras and Kodaikanal, November is the wettest month, while Bangalore, Coimbatore and Vizagapatnam receive the highest rainfall in October, Poona and Sholapur have the maximum rain in September".

By taking the flooded condition as a well-established factor to induce spawning, either directly or indirectly, *i.e.*, by providing an access to suitable shallow areas, from the above data it would appear that breeding seasons

in most fishes will not be the same in different regions. For instance, in the Chittagong Hill tracts where the first monsoon rains of the Indian sub-continent occur, the major carps breed from April to June (Ahmad, 1948). In the Ganga system of North Bihar, depending upon the occurrence of rain and flood from place to place, the breeding seasons in major carps last from April to August (David, 1959). In the western U.P. and further north in the Punjab area the same species breed in July and August (Table I), (*see* Khan, 1924, 1942 and 1943 for Punjab data).

Other riverine forms, such as cat-fishes and murrels commence breeding in many rivers in June (Table I), which is almost two to three weeks before the outbreak of monsoon rains in the western U.P. June is undoubtedly the hottest month in the plains of northern India. Most of the seasonal ponds and streams get totally dried up in this month, but the rivers, nevertheless, begin to swell due to melting snows and heavy rains in the Himalayas. Perhaps a rising level of water in these rivers provides suitable conditions to fishes to commence breeding. Peak spawning, however, follows the outbreak of monsoons.

In perennial ponds, a large number of fishes such as *Barbus stigma*, *Chela bacaila*, *Mystus vittatus* and *Ophicephalus punctatus* begin to breed towards the end of June as soon as the pre-monsoon showers have set in. In July or August after the monsoon season has too far advanced and most of the rivers, streams and seasonal ponds get flooded and low lying areas and fields are fully inundated, gravid fishes in large numbers make an access from rivers and perennial ponds to shallow areas where peak spawning occurs. Young fishes are hatched in these areas. They then begin to move in various directions along with the flood current, and in this way the dispersal of each species is effected over a wide area. This largely explains the consistent occurrence of many riverine fishes in many seasonal and perennial ponds year after year. Indeed, many freshwater fishes have a wide distribution. Some of them are recorded from all parts of India. There seems hardly any other provision to effect their dispersal all over the inland waters except flood conditions that prevail during the monsoons. Soon after the rains are over, all those areas which once became inter-connected are reduced to isolated patches or ponds and there exists a regular fishery of cat-fishes, carps and murrels in many of these ponds. An interesting case of fish dispersal was noticed by one of us (S. Z. Q.) in August 1958 when Aligarh received one of its heaviest rainfalls. The entire Civil Lines area where the University is situated got flooded and on the main highways several broods of *Ophicephalus punctatus* consisting of fry and parents

were noticed in addition to a large number of other species in fields and gardens. Some of these were rather uncommon for Aligarh.

2. Seasonal changes in temperature also seem to regulate the breeding of fishes (Fig. 5). From January onward the atmospheric temperature shows a regular rise reaching its maximum in mid-June. In these months there is also a greater range of variation in the daily maximum and minimum temperatures. Towards the end of June, after the monsoon rains have set in, the temperature falls, and throughout the monsoon months it maintains relatively a uniform range. The daily fluctuations do not exceed more than 5 to 10° C. which are in contrast to the pre-monsoon months when daily variations in temperature may be of 18 to 20° C. Soon after the monsoons are over, and the winter conditions begin to prevail, the temperature decreases. It finally reaches its minimum in January. From October onwards daily variations in temperature also become more and more pronounced.

From these data it is clear that in the plains of northern India where winter and summer seasons are so clearly defined, the only time when temperature conditions remain fairly uniform is that of the monsoons. All fishes, therefore, breed during this season. Due to prevailing flood conditions there is no competition for space. Each species, therefore, gets the best chance of finding suitable grounds to settle. Probably this is the season when most of the physical factors favour natural reproduction.

To sum up, it seems that breeding in freshwater fishes is so adjusted that the larvæ hatch during a season when conditions of temperature and shelter are at their optimum. Considering the significance of such a behaviour in terms of adaptive advantage to the species, the disparity in breeding habits is not so well marked as might be anticipated from the conditions revealed by their ovaries.

Summary

Breeding seasons of 19 different species of freshwater fishes including carps, cat-fishes, murrels, grey mullet and spiny eel were determined by following the cycles of maturation and depletion of gonads over a greater part of the year. Size frequency distributions of oocytes in various species were studied by taking maturing ovaries from the main breeding months. On the basis of the conditions revealed by the unspawned eggs, the freshwater fishes were divided into following three categories:—

(1) Those which possess a well-marked single group of oocytes.

(2) Those which contain more than one clearly defined groups.

(3) Those which have oocytes of all sizes with no well-marked batches.

The breeding season in fishes belonging to the first category is short and lasts for about two to four months. In each individual the cycle of spawning occurs only once a year and the state of maturity at any given time is fairly uniform throughout the population.

Individuals belonging to the second category have a succession of spawnings. Their breeding seasons are relatively longer and last for about four to five months. At no time of the year there is an exclusive preponderance of one maturity stage in these fishes.

Fishes belonging to the third category are characterised by a non-seasonal breeding. Gravid individuals occur over a greater part of the year and it seems that if conditions for spawning are favourable, the cycle can occur at any time of the year. Spawning in each individual is not synchronous with those of other individuals of the population.

In the plains of northern India, most fishes breed during the monsoon months when seasonal temperature remains fairly uniform. Peak spawning occurs after the monsoon rains have properly set in. There is a general delay in spawning in the western U.P. as the outbreak of monsoons is usually late.

It is suggested that the breeding cycles in freshwater fishes are well suited to the conditions that prevail in this part of the country. The breeding seasons are adapted to provide optimum conditions of temperature and shelter for the newly hatched fishes.

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OBSERVATIONS ON THE CRAB FISHERY OF MANGALORE COAST*

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Introduction

Considerable quantities of crabs are caught in the inshore waters of Mangalore coast and from the river mouths of this zone during December-June period and these find a ready market in the towns. Crabs are brought to Mangalore town from the Ullal estuary and from Kasargod, Kumbla, Bengre and Mulki centres. The fishery is more active during February–April when fishing for the shoaling fishes reaches the waning period. Unlike in other towns in the south or in the north, crab meat is very much in demand in Mangalore. On estimation, it was found that as much as 22 tons of crabs are brought to Mangalore Webster market alone every season. It may be mentioned that the total production for the Malabar coast was estimated to be only about 23 tons (Chidambaram and Venkataraman, 1944). Crab meat is also sold at as high a price as any other esteemed variety of fish at this place unlike other centres where it does not fetch a high price.

There is no detailed account of the fishery on a countrywide basis although accounts of the crab fisheries of Malabar coast (Menon, 1952), of the Chilka lake (Jones and Sujansingani, 1952) and of the Mandapam coast (Prasad and Tampi, 1952) are available for comparison. Small notes on the fishery are seen in the earlier accounts of Rai (1933), Hora (1935) and Chopra (1936). A perusal of these papers shows that the fishery is not of the same species and that the seasons, gear employed, methods of fishing and disposal are not identical.

The species that contribute mainly to the local fishery are †*Neptunus sanguinolentus* (Herbst) and *N. pelagicus* (Linnaeus). Other edible crabs such as *Scylla serrata* and *Charybdis* spp. are also encountered in small numbers. Among the two species, the former has always been found to

† The genus *Neptunus* has been synonymised with the genus *Portunus* by Stephensen and Campbell (1959).

occur in large numbers, although during certain weeks, the latter recorded increased catches particularly during the closing months of the season.

Material and Methods

Weekly collections of crabs were made from the landing centres at the estuary and at the sea-shore and also from unsorted catches brought to Webster market for wholesale disposal, from December 1958. Regular catch statistics were maintained of catches brought to the market every day. The trawl catches made, off Mangalore, by the mechanised vessels operated by the training establishment of Mysore State Fisheries Department in depths between 4 and 12 fathoms were also studied. Measurements of crabs were made by noting the length between the tips of the largest spines, as was done by Menon (1952). The data relating to the fluctuations of the crab zoea were obtained through analysis of weekly plankton collections made off Ullal in the four-fathom zone for three consecutive years from 1957.

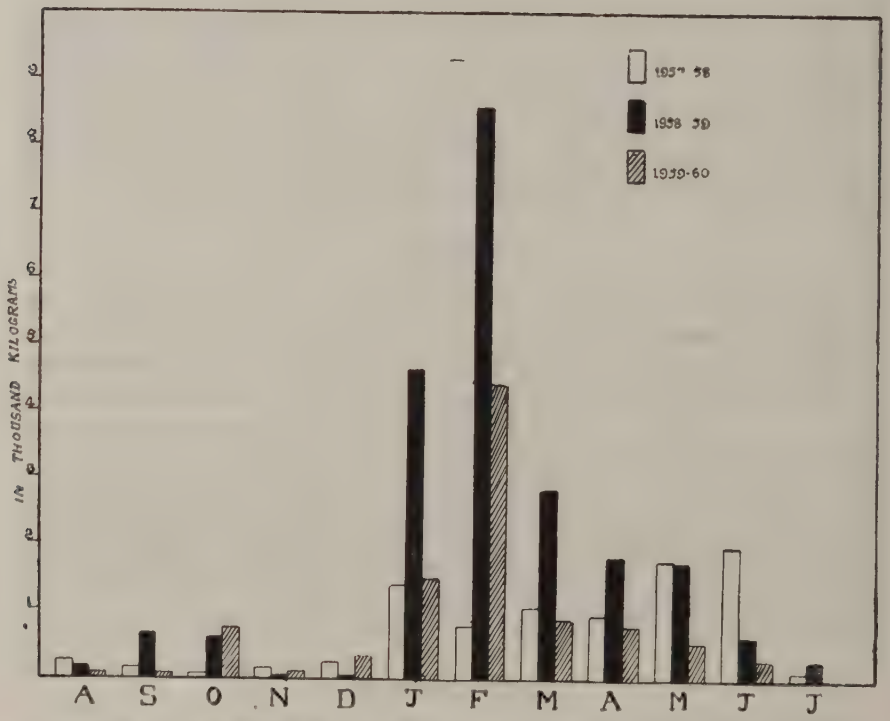
The Fishery

The crab fishery commences from January in each year although small quantities of crabs are always found in the market. During the active monsoon months crabs are fished from the river-mouths. The main season of the fishery is from February to April and comes to a close early in June, more or less coinciding with the commencement of the South-West monsoon (Text-Fig. 1). Crabs are sold by numbers in the retail sales whereas they are sold by baskets by wholesale agents. Fishing is carried out in the estuaries and in the inshore waters extending up to five or seven fathoms and the mechanised boats bring catches from depths up to 15 fathoms. The great bulk of the catches, however, are made in the shallow inshore seas within two or three fathoms and within a mile from the coast.

Fishing Methods

Crabs are caught in the *Rampani* nets, in the *Kairampani* and in the cast nets. They were recently caught in appreciable numbers from the trawl nets operated from the mechanised boats also. The indigenous gear used almost exclusively for crab fishing are the modified *Kanthabale* and *Aiburle* which are locally called *Aedi bale* (crab net). Except in the case of *Kanthabale* and *Aiburle*, the other nets are not specially designed for crab fishing although crabs along with other fishes are caught in appreciable numbers in these nets also, during certain seasons.

Menon (1952) has stated that boat-seines, gill-nets and cast nets have been used in crab fishing. Prasad and Tampi (1952) have described the *Nandu valai* used in Mandapam area to catch *N. pelagicus* and Jones and Sujansingani (1952) have given details of the *Noli jal* which is more or less similar to the *Nandu valai* with slight modifications. At Ullal and all along the Mangalore coast, fishing for crabs is carried on a very extensive scale during the summer months by employing *Kanthabale* which is a type of anchoring gill-net (Text-Fig. 2).



TEXT-FIG. 1. Histogram showing the monthly fluctuations of market arrivals of crabs in Mangalore for the period 1957–60.

The Kanthabale.—The *Kanthabale* is operated fairly widely on the Kanara coast particularly at Mangalore, Malpe and Hosabettu for inshore fisheries during the post-monsoon season. It is not uniform in piece-length or mesh size at all the centres. The one operated at Ullal, near Mangalore, for crab fishing is a hemp net with a mesh size of 50–60 mm.

The net is generally used with at least two pieces joined together. The mode of operation is the same as described by Prasad and Tampi (1951) for *Nandu valai*. Usually two or three fishermen conduct fishing operations from dug-out canoes. Generally the net is set in shallow water at a depth of nearly one to two fathoms and about 150–200 yards from the shore, about dusk. The net is anchored in position by placing heavy stones on the foot rope and the head rope is kept afloat with the help of light wooden floats. These are left overnight and the nets are hauled up early next morning before sunrise. The crabs are thus brought to the shore alive and they are removed from the nets with great care and skill.

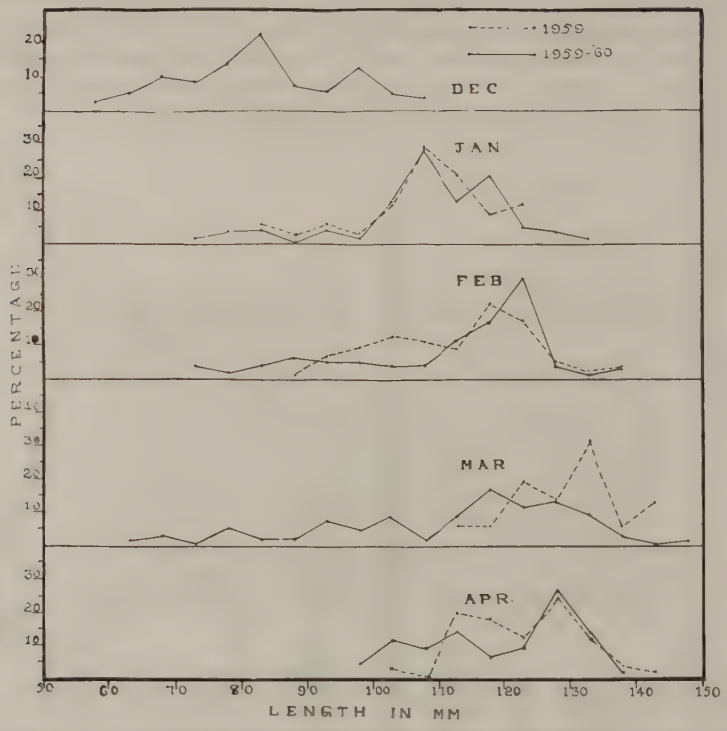
TEXT-FIG. 2. Diagrammatic sketch of *Kanthabale* operated along Mangalore coast. (A) Bamboo float. (B) Wooden float. (C) Stone weight. (D) Small stone weight.

Aiburle.—The *Aiburle* is also an anchored gilling net and resembles *Kanthabale* in structure and mode of operation but has a larger mesh size (120 mm.), increased width and is made of thicker threads. The wooden floats are longer but narrower and is operated in slightly deeper waters.

SEASONAL AND ANNUAL FLUCTUATIONS

As has been pointed out already, the season for crab fishery starts from December although smaller quantities are fished practically throughout the year. During 1957–58 about 9 metric tons of crabs are estimated to have been brought to the main market alone, whereas during 1958–59 season the catch almost more than doubled to 22 metric tons. But during 1959–60

season the fishery suffered a set-back and the catches came to the value obtained during 1957–58, to about 10 metric tons. It is not, however, possible at this stage, to state precisely the factors that bring about such sharp annual fluctuations.



TEXT-FIG. 3. Size frequency distribution of *Neptunus sanguinolentus* in the commercial catches for the period 1958–59 and 1959-60.

The active season was observed to be from January-March in all the three years of study. The highest catches were obtained during February and March in almost all the three years. The fishery comes to a close soon after the onset of the monsoon in June. Thereafter, fishing is limited to the estuary only and the small catches obtained seldom reach the main markets. Since the fishery is active at a time when the pelagic fishery season is at its closing period, the crab catches form a significant part of the edible sea food for local consumption. This is another reason for the comparatively high price for crabs at this place.

Observations on Breeding and Maturity‡

Berried females start appearing in the catches from December and their number increases as the fishery progresses, and as much as 60% of females noticed during March and April of 1960 were berried ones. During April and May 1959 the percentage rose as high as 83%. During the peak months of February-April, it can be said that nearly half the number of females caught were in berried condition. The minimum size of berried crab recorded at Mangalore during these years was 84 mm. It may, however, be recombered that Menon (1952) has recorded a still smaller size (78 mm.) for Malabar coast.

An analysis of the sexes obtained in the samples collected showed the proportion to be 54·7 : 45·3 for females and males respectively during 1959 registering small increase in proportion for females. But during 1960 season, a heavy preponderance of females was observed (63·4 : 36·6). It may perhaps be due to factors pointed out by Mackay (1946) as quoted by Menon (1952). The maximum size obtained for female was 138 mm. and for male 149 mm. The proportion of sexes obtained during the season for 1959 and 1960 are tabulated below:—

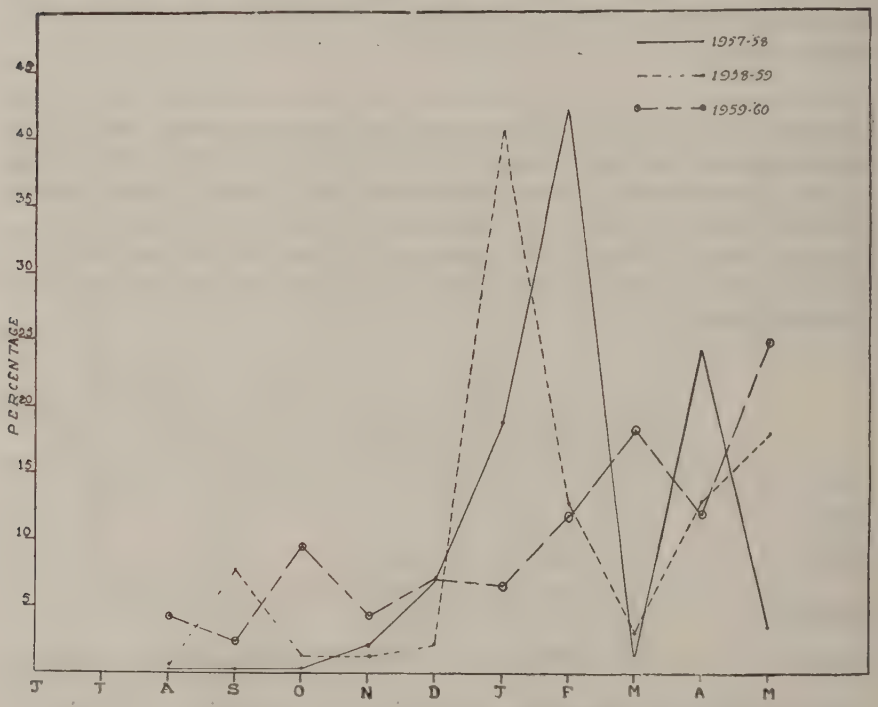
	1959		1960	
	Female	Male	Female	Male
December	..	..	52·5	47·5
January	86·2	13·8	72·2	27·8
February	63·5	36·5	70·4	29·6
March	43·8	56·2	55·8	44·2
April	46·2	53·8	67·7	32·3
May	13·3	86·7	..	..

Feeding Habits.—The food of crabs, on analysis, was found to consist of detritus, polychæte remains and bits of prawns and molluscs. There was no significant variation in the food of the adult and juveniles.

‡ The biological studies reported in this paper relate only to *N. sanguinolentus* unless otherwise stated.

Size Composition

Measurements were taken regularly from the catches at the landing places and data analysed for the two seasons of 1959 and 1960, and the results are plotted in Text-Fig. 3. It may be seen from this that there is a progressive increase in size as the commercial season advances. The shift in position of the modes may be partly due to increase in growth and may also be due to migration of larger individuals belonging to the same year-class moving into the fishing area.



Text-Fig. 4. Fluctuations of crab zœa in the inshore plankton for the period 1957–60.

While there was no significant difference in size composition in the catches brought from the indigenous crafts operating close to the shore irrespective of the gear employed, the trawl catches, brought from 10 fathoms and beyond, showed increase number of smaller sized individuals. This might indicate that the mature ones migrate into the inshore zone and the movement may mainly for spawning. Menon (1952) has indicated the possibility of an annual migration. A comparative study of the trawl catches in the deeper waters and the *Kanthabale* catches of inshore waters confirm

this inference. It is likely that the juveniles may go to deeper waters and return to the inshore ground when they are mature indicating an inward-outward migration off Mangalore for this species. This view has gathered further strength due to the increased proportion of berried females in the inshore catches and their insignificant representation in the trawl catches. The proportion of berried crabs obtained in the trawl catches and in the indigenous crafts during the season for 1959 and 1960 are tabulated below:—

	1959		1960	
	Indigenous craft	Mechanised vessel	Indigenous craft	Mechanised vessel
December	..	..	9·5	..
January	56·0	..	38·5	..
February	55·0	..	55·0	36·1
March	57·1	..	60·0	16·6
April	83·3	16·7	47·8	20·0
May	81·1	20·0	..	..

The total frequencies of the species showed only a single mode of 116–125 mm. during both the years indicating a single size-group dominating the fishery during the commercial season.

Fluctuations of Crab Zœa in the Inshore Waters

The zœa of *N. sanguinolentus* was described by Naidu (1955), from Waltair coast and she has used the structure of the antennæ as the diagnostic character to differentiate the three species. However, in this account no attempt is made to study the fluctuations of the zœa larvæ of the different species and the larvæ are treated as one unit for study.

On analysis of the weekly plankton collections made at the four-fathom area off Ullal, Mangalore, it has been found that the brachyuran zœa start appearing in the plankton soon after the S.-W. Monsoon. But during these post-monsoon months up to December their number remain appreciably low except for a small rise during the September-October period. But larvæ start appearing in the plankton in fairly large numbers from January onwards and during February, March and April, a peak of larval occurrence is observed. The case was found to be similar in the subsequent years also (*see* Text-Fig. 4). The season of occurrence of increased numbers of berried

crabs in the fishery almost coincides with this peak in occurrence of crab zœa in the plankton.

The occurrence of larvæ continues up to May and thereafter they are scarce; but the collection maintained during the rainy season from the estuary reveals smaller numbers of them up to the end of June. The megalopæ and juvenile crabs appear in the dredge collections made from August onwards. Very small crabs are found to congregate near Ullal bridge up the estuary soon after the vigour of the monsoon subsides. This is in general agreement with the observation of George (1958) in Cochin waters that brachyuran zœa are present in large numbers during December-May reaching the peak in January and February, with a minor peak during October.

Acknowledgements

The authors are grateful to Dr. S. Jones, Director, for encouragement and to Shri M. Krishna Menon for helpful criticism of the MSS and to the Mysore State Fisheries Department at Mangalore for allowing them to study the catches of crabs brought by the mechanised vessels. They are also grateful to Shri K. K. Parameswara Menon for help in the preparation of the illustrations.

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INDEX OF PREPONDERANCE—A METHOD OF GRADING THE FOOD ELEMENTS IN THE STOMACH ANALYSIS OF FISHES

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(Central Inland Fisheries Research Substation, Allahabad)

Introduction

Various methods are in prevalence in the studies of stomach analysis of fishes and these were critically discussed by Hynes (1950) and Pillay (1952). They comprise chiefly in studying the frequency of occurrence of food items as well as bulk. The 'occurrence' method is insulated from the quantitative element and similarly quantitative methods of 'occurrence' element. On account of the restricted scope of these two types of analyses they are individually not suited for the purpose of grading the food components of gut contents. An Index taking these two factors into consideration seems to be desirable for this purpose and accordingly a composite Index—designated as the 'Index of Preponderance'—was constructed from volume and 'occurrence' index. The mean Index of feeding, proposed by Iizuka *et al.* (1954) is different in scope and considers the ratio of volume of the feed to volume of animal, the volume being treated as a function of length. Their method gives an index of feeding intensity.

Scope of Existing Methods

The occurrence method examine the stomach contents from only one standard, *i.e.*, the physical presence of an organism. This method is not governed or influenced by the size or numbers of food organisms. For instance, three organisms in a stomach, say, prawn, rotifers and diatoms, present in the ratio of 1 : 200 : 2000 would all be treated by this method as 1 : 1 : 1 with reference to the stomach in question. The method holds good even when there is differential distribution of various food organisms in the water for the same reason that it is not biased by size or numbers of organisms comprising the food. While this method registers the frequency of occurrence of various food components in the gut samples it vitally lacks the quantitative element in it.

The bulk of the food items could be evaluated in three ways. They are: (1) Numerical, (2) Volumetric and (3) Gravimetric. The number

method is not suited to the Index as in conjunction with the frequency of occurrence it magnifies the importance of smaller organisms which may appear in enormous numbers. This defect, however, could be remedied by methods of 'weighting' frequently followed in the Index construction (Croxton and Cowden, 1955). This aspect is, in a way, covered by points (numerical) method which attempts to assess the various items of food against a standard unit. As this method provides scope for personal judgement it was also not considered for the construction of the Index. The volumetric methods are by far the best to assess the various food items quantitatively. Here again the displacement method yields greater accuracy of evaluation than points (volumetric) method as well as ocular estimations as the latter two are subject to personal error. The gravimetric could, no doubt, be as accurate as volumetric but the latter is more accessible and easier to evaluate than the former. The various quantitative methods discussed above, while giving the quantitative dimension to the food items, lack the 'occurrence' element.

Index of Preponderance, Its Scope and Construction

In order to get a summary picture of frequency of occurrence as well as bulk of various food items an Index taking into consideration, these two factors, is indicated. Before proceeding with the construction of the Index it is desirable to examine its constituents. Occurrence of food items could be examined in two ways: (1) Number of fish in which each food item occurs is given as the percentage of the total number of fish examined, *i.e.*, if out of N fish examined, n_i fish contain the food i, then the percentage of food i is given by $n_i/N \times 100$. (2) Total number of occurrences of all items is summed and scaled down to given the percentage composition of diet, *i.e.*, if food i occurs n_i times, then the percentage of occurrence of food i may be given as $n_i/\Sigma n_i \times 100$. The first way of analysis is unsuitable as the per cent. occurrence of food items do not sum up to 100. For an Index, to be good, the sum of indices should preferably add up to 100 or 1. Consequently the second method of analysis of occurrence whose individual percentages add up to 100 is chosen. As the percentage volume of food content is determined from the total volume of all contents their aggregate total up to 100. Mathematically this is similar in procedure as the second method of analysis of occurrence.

If v_i and o_i are the volume and occurrence index of food item i (as indicated by their percentages) the combined Index (I) for food i may be presented as follows:—

$$I_i = \frac{v_i o_i}{\Sigma v_i o_i} \times 100$$

(the sum of all items leads to 100. The Index, designated as the Index of Preponderance, is, in actuality, a composite one based on volume and occurrence Index. The composite Index is similar in construction as the density per unit area).

The Index provides a definite and measurable basis for grading the various food elements as it gives a combined picture of frequency of occurrence as well as bulk. The advantages of grading food elements in the studies of food analysis are immense especially in open water fishes where animals have access to diverse organisms. The ranking would undoubtedly assist in assessing the food proclivities of the animals. The 'occurrence' estimation, no doubt, gives certain indications about food preferences of the animal but since it is not governed by the size, number or quantity of the food items its utility to that extent is limited. However the food preferences of fish are more clearly accentuated by the Index of Preponderance which takes into consideration both the volume and frequency of occurrence of food items, *i.e.*, food habits of the fish is more decisively brought out by the consistent occurrence of a food in good volume than by any partial examination by volume alone or frequency alone which would only give incomplete picture. Here, of course, incidental and accidental inclusions like sand, mud, etc., have to be excluded from consideration. The state of digestion of food items in stomach and rectum will provide a clue whether a food item is important or not, *i.e.*, whether a food item is being utilised or not in metabolism. The Index of Preponderance which is not merely a useful tool to study the food preferences of the fish but assumes biological significance when examined against the state of digestion of food items in stomach and rectum. The proposed Index thus fulfils:

(1) the sum of the indices adds up to 100,

(2) it does not conflict with any of the existing indices,

(3) it has physical meaning but assumes biological significance when the Index is examined against the state of digestion of food organisms in stomach and rectum.

The Index of Preponderance could have been constructed in a different way by taking the geometric mean of volume and occurrence index. But this Index seems to have certain limitations, for example, that when percentage of occurrence is constant for all food items the Index should be proportional to volume of all items and *vice versa*. This is not so, for, if

the percentage of occurrence is constant the Index is proportional to the square-root of the per cent. volume and *vice versa* for which, *prima facie* there is no justification. The present composite Index—Index of Preponderance—does not suffer from this deficiency and consequently the more suitable.

The Application of 'Index of Preponderance' to the Food Studies of *Catla*

The 'Index of Preponderance' of food items of adult and juvenile *Catla catla* (Ham.) has been presented in the last column of Tables I and II with rankings in brackets. According to Index the food items may be graded as follows: for adult *Catla*, crustacea (1), algæ (2), plants (3), rotifers (4), insects (5), decayed organic matter (6), sand and mud (7) (this item may be excluded), and protozoa (8), and similarly for juveniles, crustacea (1), algæ (2), rotifers (3), insects (4), plants (5), protozoans (6), sand and mud (7) (this item may be excluded), decayed organic matter (8), molluscs (9) and polyzoa (10).

Table I

Index of Preponderance (based on gut samples collected in the year 1959) of adult Catla

Food items	Percentage of occurrence (o_i)	Percentage of volume (v_i)	$v_i o_i$	$\frac{v_i o_i}{\Sigma v_i o_i} \times 100$
Crustacea	24·5	57·1	1398·95	64·20 (1)
Algæ	27·3	24·0	655·20	30·06 (2)
Plants	6·4	8·2	52·48	2·41 (3)
Rotifers	10·8	2·4	25·92	1·19 (4)
Insects	3·6	6·0	21·60	0·99 (5)
Protozoa	0·6	0·3	0·18	0·01 (8)
Molluscs	..	..	..	..
Polyzoa	..	..	..	..
Decayed organic matter	10·0	1·3	13·00	0·60 (6)
Sand and mud ..	16·8	0·7	11·76	0·54 (7)
Σ ..	100·0	100·0	2179·09	100·00

TABLE II

Index of Preponderance (based on samples collected in the year 1959) of juvenile Catla

Food items	Percentage of occurrence (o_i)	Percentage of volume (v_i)	$v_i o_i$	$\frac{v_i o_i}{\Sigma v_i o_i} \times 100$
Crustacea	25·8	63·8	1646·04	79·68 (1)
Algæ	19·8	10·2	199·92	9·68 (2)
Plants	5·9	3·6	21·24	1·03 (5)
Rotifers	14·8	7·9	116·92	5·66 (3)
Insects	5·4	11·0	59·40	2·87 (4)
Protozoa	9·4	1·1	10·34	0·50 (6)
Molluscs	1·3	0·5	0·65	0·03 (9)
Polyzoa	0·6	0·7	0·42	0·02 (10)
Decayed organic matter	5·3	0·5	2·65	0·13 (8)
Sand and mud ..	11·9	0·7	8·33	0·40 (7)
Σ ..	100·0	100·0	2065·81	100·00

A perusal of indices indicates that crustacea and algæ constitute 1 and 2 ranks both in juveniles and adult *Catla*. While third, fourth and fifth places are held by plants, rotifers and insects in adult, there is a slight change in emphasis in juveniles, where similar positions were held by rotifers, insects and plants. In grading the food elements accidental and incidental inclusions like sand, mud, etc., may be left out of consideration. As has already been said the Index would assume biological significance as well if the state of digestion of various food items is also taken into consideration. For example if crustacea were found in all states of digestion in the gut contents—as it seems to be the case in *Catla*—obviously they are being utilised by the animal. In that case the Index has not only physical meaning but biological significance as well.

SUMMARY

Grading the gut contents of the fish gives indications of the food preferences of the fish. The methods of analysis that are now being followed

are, individually, not suited for this purpose. An Index has been proposed for this purpose which takes into consideration both frequency of occurrence and bulk of the food items. The Index assumes biological significance when it is considered along with the state of digestion of food items in stomach and rectum. The construction of the Index and its scope are discussed. The application of Index was attempted on the food studies of *Catla*.

Acknowledgement

Thanks are due to Dr. M. P. Motwani for his comments and criticism; similarly to Messrs. K. K. Ghosh and K. H. Sujansingani for their valuable suggestions in the mathematical part of this paper. The opinion expressed and elaboration attempted in this paper are those of senior author and do not commit anybody acknowledged here. Sincere thanks are also due to the referee for suggesting the present mode of construction of the Index of preponderance.

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STUDIES ON THE FISHERY AND BIOLOGY OF THE COMMERCIAL CAT-FISHES OF THE GANGA RIVER SYSTEM

I. Early Life-History, Bionomics and Breeding of *Mystus* (*Osteobagrus*) *seenghala* (Sykes)

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Introduction

The two species of Gangetic *tengra*, *Mystus* (*Osteobagrus*) *aor* (Hamilton) and *Mystus* (*Osteobagrus*) *seenghala* (Sykes) are widely distributed of the freshwater species of cat-fishes in India, occurring in almost all the principal river systems of India, Pakistan and Burma. In the Ganga River system, the two species constitute fishery of considerable commercial importance throughout the year and data relating to commercial landings over a number of years, reveal that their fishery ranks next only to that of *Hilsa ilisha* (Hamilton) and *Cirrhinus mrigala* (Hamilton). During certain months, particularly in late winter and early summer, the two species of *Mystus* form the most dominant fishery. Both these species attain a large size (*cf.* Day, 1878) and we have observed a maximum length of 1120 mm. in respect of *M.* (*O.*) *aor* and 1146 mm. in *M.* (*O.*) *seenghala*. In spite of their large size and great economic value, very little is known about the fishery and biology of the two species except for a few observations on their breeding and feeding habits (*cf.* Chacko and Kuriyan, 1948; Khan, 1924, 1934; Raj, 1940) and Jhingran (1956) has discussed their fishery from the 30–mile stretch of the Ganga around Buxar, Bihar. The two species were therefore taken up for detailed investigations in the research programme of the Central Inland Fisheries Research Substation at Allahabad and the work was commenced in November, 1955.

In the present communication, which is the first in a series on the fishery and biology of commercial species of freshwater cat-fishes of the Ganga River, embryonic and larval development of *Mystus* (*Osteobagrus*) *seenghala* (Sykes), along with observations on its breeding habits and bionomics of larval stages, are described.

The fertilised eggs, 168 in number, collected on 29-4–1960 as a single lot from a breeding pit in the Ganga River near Badanpur, about 30 miles

upstream of Allahabad, were immediately brought to the laboratory and microscopic examination showed that all the eggs appeared to be in the same state of embryonic development. The hatched-out larvæ were reared under laboratory conditions and a connected series of larval stages of *M.* (*O.*) *seenghala*, up to a stage in which most of the adult characters of the species are manifest, were obtained.

Description of Egg

The fertilised egg of *M.* (*O.*) *seenghala* is double-walled, spherical and demersal. Its diameter ranges between 1·60 mm. and 2·15 mm. with maximum number of eggs of 1·95 mm. as shown by measurements of 56 eggs (Fig. 1). The egg proper is enclosed in an inner smooth, thin and transparent

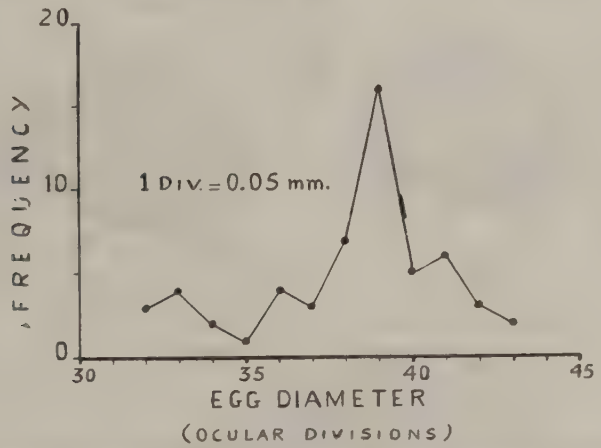

Fig. 1. Diameter frequency of developing eggs of *Mystus* (*Osteobargus*) *seenghala* (Sykes).

vitelline membrane. The outer tough membrane, the zona radiata, is heavily laden with fine particles of silt and sand suggesting its adhesive quality. It was possible to clear the zona radiata of the foreign particles to reveal that the membrane is smooth and transparent. The perivitelline space, unlike in the egg of *Rita rita* (Karamchandani and Motwani, 1955), is very much reduced and distance between the two membranes ranges from 0·2 to 0·3 mm. only. The yolk, brownish-yellow in colour, is distinctly reticulate and without any oil globules. Preservation in 4 per cent. formaldehyde imparts opacity to the developing egg and segmented structure of the yolk is also obscured. For facilitating sketching of different embryonic stages, the egg membrane was therefore teased to remove the embryos.

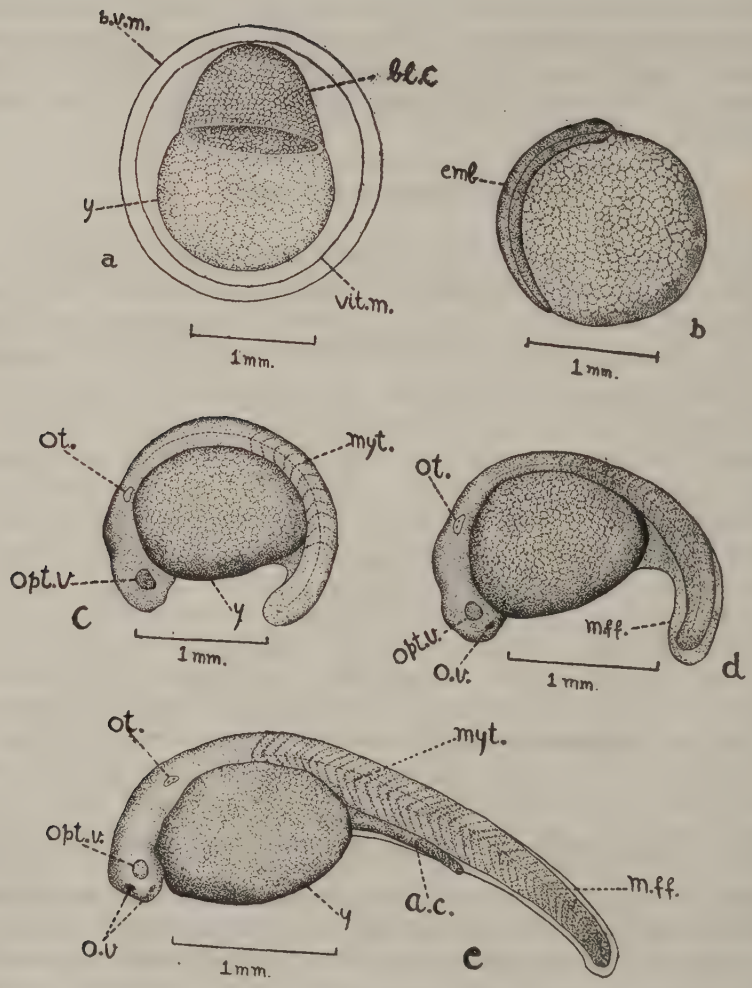

FIG. 2. Embryonic stages of *Mystus* (*Osteobagrus*) *seenghala* (Sykes). (*a*) X hours old embryo; (*b*) X + 2½ hours old embryo; (*c*) X + 4½ hours old embryo; (*d*) X + 8 hours old embryo; (*e*) X + 18 hours old embryo.

a.c., alimentary canal; *bl.c.*, blastodermal cells; *emb.*, embryo; *m.ff.*, median fin-fold; *myt.*, myotome; *o.v.*, olfactory vesicle; *opt.v.*, optic vesicle; *ot.*, otolith; *ot.c.*, otic capsule; *p.v.m.*, peri-vitelline membrane; *vit.m.*, vitelline membrane; *y.*, yolk.

Embryonic Development

Stage I: X hours old (Fig. 2, *a*)

At this stage the segmentation has progressed considerably so that the fissures, incident to cell divisions, are greatly obliterated. In the side view the dome shape of the blastoderm is very distinct. The germ ring is not yet formed.

Stage II: X + 2½ hours old (Fig. 2, *b*)

The blastodermal cells have completely invaginated the yolk and the germ ring is seen as a marginally thickened band round the yolk sphere. A slight thickening at one end of the embryonic ridge differentiates the cephalic region.

Stage III: X + 4½ hours old (Fig. 2, *c*)

The rudimentary optic vesicles are formed in greatly pronounced cephalic region of the embryo. Yolk is pear-shaped (length 1·32 mm., maximum width 1·00 mm.). A small distal portion of posterior end is separated from the yolk and membraneous matrix occupies the space between yolk and ventral side of the caudal region. The paired otic capsules made their appearance but otoliths have not yet formed therein. 11 myotomes are discerned.

Stage IV: X + 8 hours old (Fig. 2, *d*)

Embryo has developed 21 myotomes. Yolk is further absorbed (length 1·22 mm., maximum width 0·93 mm.) and consequently considerable portion of the caudal region is free from yolk. The optic vesicle is enlarged but lens is not formed. Otoliths are distinctly visible. The olfactory vesicles appear for the first time at this stage as small faint depressions anterior to the optic vesicles. A simple bulge, destined to be the heart, is discerned in the ventral aspect (not shown in the figure) near the margin of yolk-mass slightly posterior to the optic vesicles. It beats rhythmically with about 50 beats per minute. Slight twitching movement of the embryo is observed. A faint streak destined to become the gut is apparent in the membraneous matrix. Embryonic fin-fold is present as a thin, continuous strip on dorsal and ventral aspects of the caudal region.

Stage V: X + 18 hours old (Fig. 2, *e*)

The cephalic region is well formed with anterior portion free from yolk. The rudimentary noto-chord, with formation of cells therein, is distinct even in anterior region of the embryo and 41 myotomes are discerned. The pear-shaped yolk is further absorbed (length 1·20 mm., maximum width 0·85 mm.).

The gut, as a straight tube, is further developed and extends up to 21st myotome. The embryo appears to be fully formed and executes vigorous rhythmic movements.

The embryos begin to hatch out after three to four hours.

Hatching and incubation period.—The developing eggs were collected on the morning of 29th April 1960, between 8–30 and 9–45 hours. Temperature of river-water at the time of collection was 23° C. The eggs were brought to the laboratory in sediment clear river-water and observations commenced at 12–30 p.m. Temperature in hatching jars during incubation period ranged between 23 and 25° C., and embryos took about 21 to 22 hours to hatch out after the earliest stage described which was fixed at 9–00 a.m. At this stage cell division had advanced considerably and dome-like shape of the blastoderm is distinct. The embryonic streak is formed two hours after. Keeping in view the fact that subsequent development was spread over 21–22 hours it is reasonable to assume that at least 3–4 hours must have lapsed before the fertilised eggs developed to the *X hours old* stage. Thus the incubation period of *M.* (*O.*) *seenghala* would be normally 24–26 hours at water temperature of 23–25° C.

The actual process of emergence of embryo from the egg case takes about 6 minutes. The vigorous and rapid thrashing movements of the embryo distorts out of shape the egg-case which soon after breaks, and with its caudal region first, the embryo emerges gradually through the " birth-pore " by periodic lashing movements of its tail.

Larval Development

Stage I: Newly hatched larva (Fig. 3, *a*)

Total length of body	4·20 mm.
Maximum height of body (including yolk) ..	0·90 mm.
Length of yolk	1·17 mm.
Maximum width of yolk	0·80 mm.
Height behind vent (including embryonic membrane)	0·47 mm.
Pre-vent distance	2·60 mm.

It is slender, transparent and devoid of pigmentation excepting on the yolk proper. Mouth is not formed, eyes in which lens formation has advanced are comparatively larger and otoliths are distinct. There is a faint indication of the rudimentary tubular heart. The moderately elongated

gut extends up to 22nd myotome and in all 51 myotomes are discerned. The larva is generally quiescent and remains at the bottom resting horizontally on its yolk.

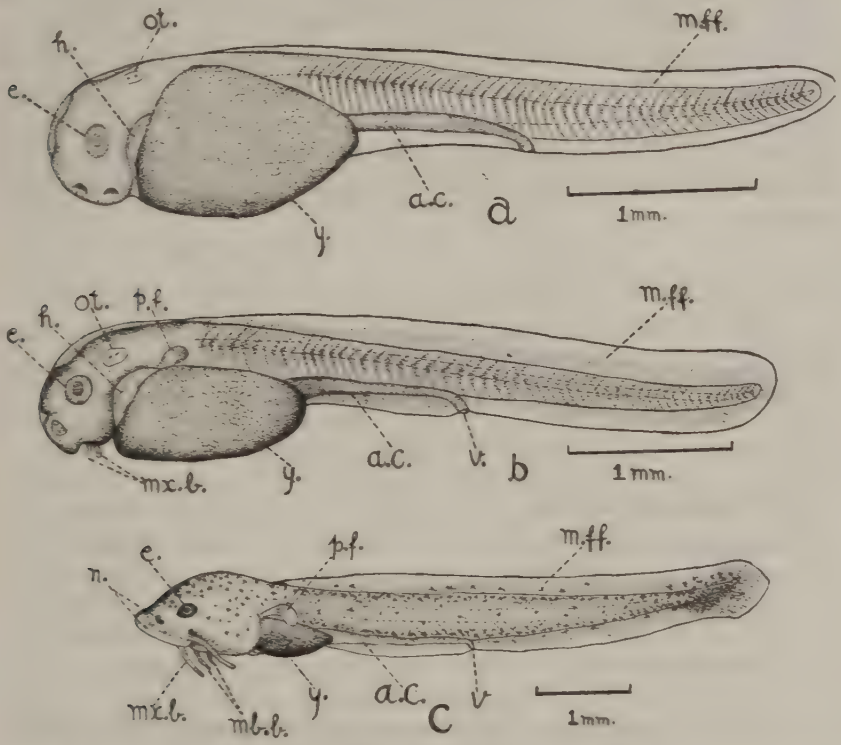

FIG. 3. Larval stages of *Mystus* (*Osteobagrus*) *seenghala* (Sykes). (*a*) Newly hatched larva; (*b*) 20 hours old larva; (*c*) 3½ days old larva.

a.c., alimentary canal; *e.*, eye; *h.*, rudimentary heart; *mb.b.*, mandibular barbel; *mx.b.*, maxillary barbel; *m.ff.*, median fin-fold; *n.*, nostril; *ot.*, otolith; *p.f.*, pectoral fin; *v.*, vent; *y.*, yolk.

Stage II: 20 *hours old larva* (Fig. 3, *b*)

Total length of body	4·50 mm.
Maximum height of body (including yolk) ..	0·85 mm.
Length of yolk	1·15 mm.
Maximum width of yolk	0·57 mm.
Pre-vent distance	2·60 mm.

The head is conspicuous and is detached from yolk-mass. Formation of stomodæum or the mouth-cleft is faintly indicated in ventral aspect, and rudimentary maxillary barbels make their appearance. Eyes have acquired distinct pigmentation. The heart is clearly seen as a tubular structure with rhythmic pulsation of 76 beats per minute. The posterior margins of the embryonic operculum are faintly differentiated and rudimentary gills are faintly perceived through the transparent operculum. The anal opening is distinct and development of digestive tube has commenced. The pectorals, as membraneous outgrowths, have made their appearance. A few faintly developed melanophores are seen in the cephalic region. Yolk is further absorbed.

Stage III: 40 *hours old larva*

Further development in the head region is evident. The ventrally placed mouth-cleft is obscured by protruding snout. Pigmentation in the cephalic region is further accentuated. The larva is 5·25 mm. in length.

Stage IV: $3\frac{1}{2}$ *days old larva* (Fig. 3, *c*)

Total length of body	6·75 mm.
Length of head	1·35 mm.
Maximum height of body (including yolk) ..	0·80 mm.
Diameter of eye	0·23 mm.
Pre-vent distance	3·60 mm.

The head is well formed with snout moderately sloping. Yolk is further absorbed and has lost its pear-like shape (length 0·25 mm., maximum width 0·20 mm.). Eyes are small and fully pigmented. The nares are conspicuous. Vent is located at 24th myotome. Both the jaws are studded with several rows of fine-pointed teeth directed inwardly. Maxillary barbels have grown in length and two pairs of mandibular barbels make their appearance at this stage with the outer pair twice as long as the inner pair. The pectorals have further broadened but are still membraneous. The caudal end of the vertebral column shows an upward kink and in its ventral aspect, slight thickening, suggestive of formation of hypurals, is indicated. The rudimentary rays or ceratotrichia are faintly discerned in caudal portion of the median fin-fold. Heavy pigmentation is evident along dorsal and lateral aspects of the body with large stellate melanophores conspicuous in the cephalic and caudal regions.

Post-Larval Development

Stage I: 7 days old

The larva is 9·5 mm. in length in which the cephalic region is well formed. Yolk is completely absorbed and instead a small oval-shaped stomach is faintly seen. Anterior nares appear as small pits and posterior cup-shaped nares are well defined. Nasal barbels have not yet developed. The median fin-fold commencing at 5th myotome is continuous and quite broad. A slight notch has developed at about 17th myotome differentiating the area of dorsal fin. Vent lies at about 23rd myotome. Pigmentation of head is considerably more pronounced.

Stage II: 10 days old (Fig. 4, *a*)

The larva is beginning to acquire the form and contours of the adult and more or less resembles it in general appearance. The head, fairly broad and deep posteriorly, is compressed dorso-ventrally in the region of orbits so that in dorsal aspect it appears oblique in relation to the snout and the two lateral sides. Snout is prolonged, obtusely rounded with sharp angles at the jaws. The larva is heavily pigmented with clusters of melanophores concentrated in the head region and along the length of the body. There is a slight indication of nasal barbels between anterior and posterior nares. The other three pairs of barbels are all developed. The median fin-fold which commences at 5th myotome is continuous and some thickening of the membrane is discerned in the area destined to become the dorsal fin. Faint indications of radials are evident both in the dorsal and the anal fins which have begun to differentiate. The oblique twist of posterior tip of the vertebral column is now pronounced and about 11 rays have developed from rudimentary hypural plates. A slight notch is apparent in the caudal fin. Some rays are differentiated in the pectoral fin. Vent lies at 23rd myotome. The larva commences feeding at this stage.

Stage III: 18 days old (Fig. 4, *b*)

At this stage characteristics of the adult are further accentuated. The head is further compressed dorso-ventrally and gape of the mouth, which is distinctly ventral, extends up to the base of maxillary barbels. Dorsal fin is free in which 8 rays are discerned. Anal fin is further differentiated by a deep notch in the fin-fold and 11 rays with articulations are evident. Ventral fin buds appear as small thickenings in the region between 17th and the 20th myotomes, but no rays are indicated. Caudal fin, slightly forked at this stage, has developed 19 rays. The first ray of the pectoral fin is covered by a sheath. The short nasal barbels have grown.

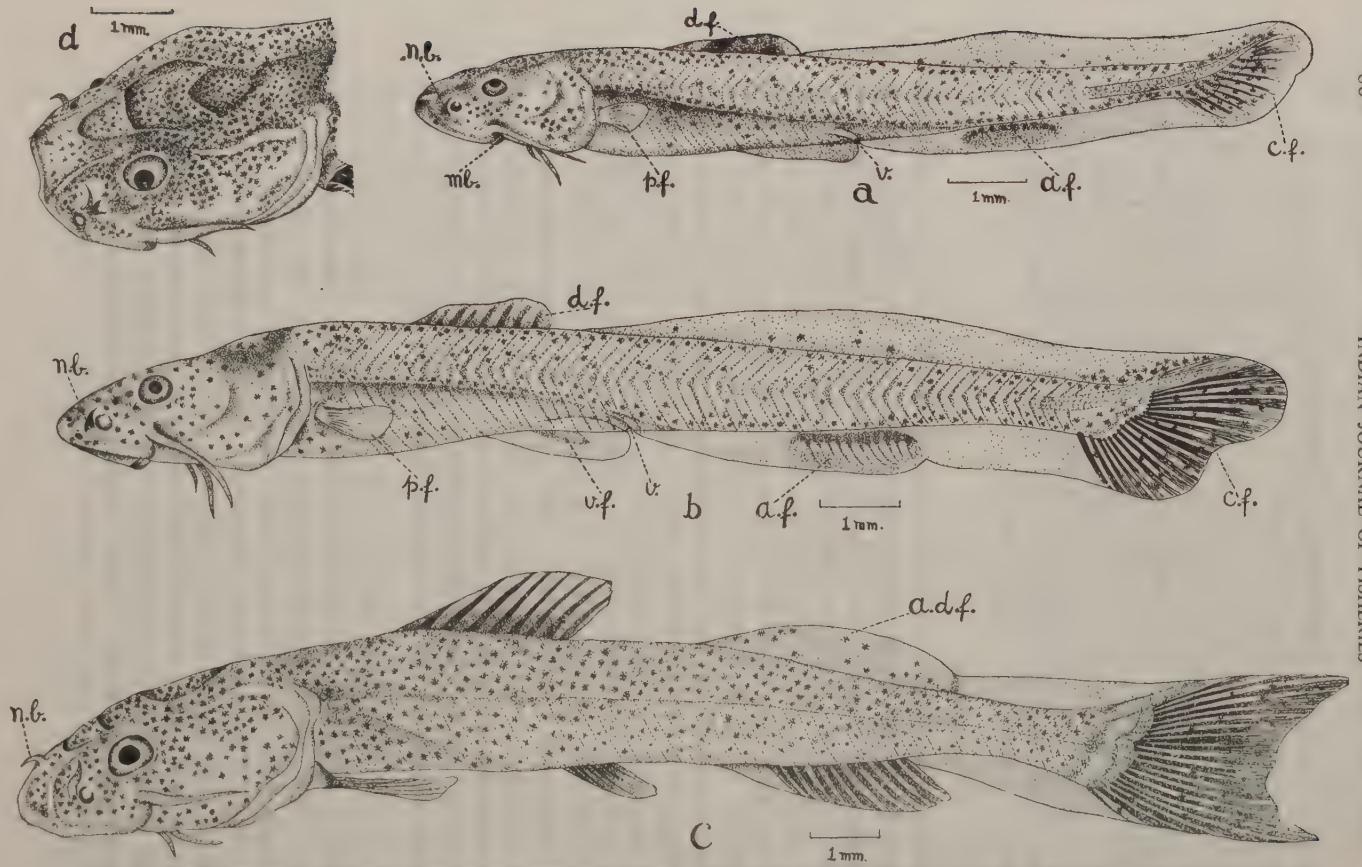

FIG. 4. Larval stages of *Mystus* (*Osteobagrus*) *seenghala* (Sykes). (*a*) 10 days old stage; (*b*) 18 days old stage; (*c*) 23 days old stage; (*d*) Dorsal view of cephalic region of 23 days old stage showing distributional pattern of stellate melanophores.

ad.f., adipose dorsal fin; *a.f.*, anal fin; *c.f.*, caudal fin; *d.f.*, dorsal fin; *mb.*, mandible; *n.b.*, nasal barbel; *p.f.*, pectoral fin; *v.*, vent; *v.f.*, ventral fin.

Stage IV: 23 *days old* (Fig. 4, *c* and *d*)

The larva has developed the form and shape of the adult. While the body is comparatively slim, the shape of head is characteristic of the adult of the species. There is a distinct depression in the frontal region of the head which in the case of the adult is reduced to a mere groove. The head, in its dorsal aspect, is oblique in the region of orbits, sloping gradually towards the tip of the snout, but in ventral aspect it is almost straight. Snout is blunt and mouth is ventral and horizontal. The first spine of the pectoral is ossified and bears on its inner margin 3 fairly large denticles. A full complement of rays are present in all the fins of which the dorsal is free. Caudal fin, with upper lobe the longer, is still connected both dorsally and ventrally by fin-fold. Ossification of chondocranium and vertebral column has commenced. The maxillary barbels have grown larger and stumpy. Pigmentation is distinctive and distribution of stellate melanophores in the head region to form the characteristic pattern of the juveniles of the species is well marked (*cf.* Fig. 4, *d*).

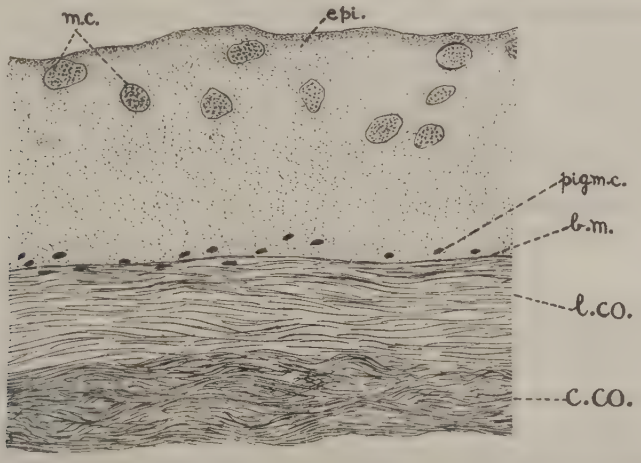

Fig. 5. Vertical section of skin (× 440) from ventral region of the spent male of *Mystus* (*Osteobagrus*) *seenghala* (Sykes).

b.m., basement membrane; *c.co.*, compact corium; *epi.*, epidermis; *l.co.*, loose corium; *m.c.*, mucus cells; *pigm.c.*, pigment cells.

An account of the position and shifting of vent in various developmental stages is given below.

In 4·25 mm. stage the vent lies much nearer to the caudal end than to the snout (1·65 mm. from vent to caudal end). Subsequently, it shifts forward and is located near the centre of the body in 11·5 mm. stage (5·75 mm. from

snout to vent). In later stages there is a further forward shift and its position is in the anterior half of the body (8·5 mm. from snout to vent) in 18·0 mm. stage, located between the 20th and the 21st myotomes.

Table I presents a number of measurements of different parts of the body of some of the larval stages described.

TABLE I

Measurements of different parts of the body in various larval stages of Mystus (Osteobagrus) seenghala (*Sykes*)

Measurements of body parts (in mm.)	3½-day old	7-day old	10-day old	18-day old	23-day old
Total length (from tip of snout to tip of upper lobe of caudal fin)	6·75	9·50	11·50	15·00	18·00
Maximum height of body ..	0·80	1·10	1·42	1·70	2·30
Length of head ..	1·35	2·00	2·40	3·65	4·10
Diameter of eye ..	0·23	0·30	0·38	0·55	0·75
Distance between snout and eye ..	0·45	0·70	0·90	1·10	1·35
Distance between snout and vent	3·60	5·20	5·75	7·15	8·50

NOTE ON BIONOMICS

Fry of *M.* (*O.*) *seenghala* were difficult to rear and grow in captivity. Several attempts at feeding and otherwise keeping the young fish alive, after absorption of yolk, were made in the laboratory but with indifferent success. Fry were placed in glass troughs and supplied with running river-water stored in a reservoir, from which it was thought they might secure some natural food. Attempts at feeding them in turn on plankton organisms (like copepods, rotifers and cladocera), *Chironomid* worms, Dipterus larvæ and macerated white of semi-boiled egg were also met with failure. A number of fry and fingerlings in the size range of 15 to 40 mm. in length, collected from breeding pits in the Ganga River, were examined and their gut contents were found to be made entirely of thick whitish scum. Raj (1940), observing that *M.* (*O.*) *aor* and *M.* (*O.*) *seenghala* exhibit a phenomenon of parental care, stated that on the body of one of the parents a whitish secretion is deposited in the form of a scum on which the young ones probably appear to feed. Our present observations amply support this view. The

developing fry and fingerlings were found to readily accept and relish the creamy white scum which is confined only to the ventral aspect of the spent males of *M.* (*O.*) *seenghala*. The fact that ventral region of the guarding male is peppered with tiny blood spots suggests that under natural conditions the young fish obviously nibble at this whitish substance resulting in numerous minute cuts in the skin of the parent.

The young fish, once it attains a length of about 45 mm., resorts to normal feeding activity. 80 specimens of *M.* (*O.*) *seenghala* in the size range of 49 to 100 mm. in total length, collected from the Ganga River in May and June 1960, were examined for food studies. Fingerlings, 49 to 70 mm. in length, according to the contents of 48 stomachs, subsist almost wholly on insect larvæ (approx. 84 per cent.) supplemented by cladocera (approx. 16 per cent.). In the insect diet, *Chironomid* worms, *Dixia* sp., *Eristalis* sp., and Coleoptera larvæ constituted the bulk. Sand grains and debris were generally not present in the guts examined.

Juveniles, ranging in length from 75 to 100 mm., as indicated by the contents of 32 stomachs, subsist mainly on teleosts and crustaceans. Teleosts (mainly represented by *Aspidoparia morar*, *Puntius* spp., *Setipinna phasa*, young of clupeids) formed 54 per cent., crustaceans (shrimps, cladocera) 33 per cent. and insect larvæ (*Chironomids*, *Dixia* sp., *Eristalis* sp., Coleoptera) 13 per cent. of the contents. Sand grains and debris were encountered frequently in the guts examined. The diet does not change greatly after the fish reaches a length of 100 mm., although larger representatives of the classes of foods mentioned are taken.

The foods of *M.* (*O.*) *seenghala* at fingerling stage occur largely on the bottom only suggesting that fingerlings feed at bottom and along the margin. The nature of diet of juveniles, however, suggests that they are column and marginal feeders.

Note on Breeding

Mystus (*Osteobagrus*) *seenghala* has been observed to exhibit the phenomenon of parental care. Raj (1940) recorded for the first time that *M.* (*O.*) *aor* and *M.* (*O.*) *seenghala* make their nests among rocks on stream beds in April and May, and in each of the three nests observed, he found only one parent along with the young ones (but no eggs) which appeared to be feeding on white secretion exuding from the inflamed ventral surface of the parent. During certain riverine investigation in the River Sone, a major tributary of the Ganga in Bihar, the two species were found making nests in March 1953 on soft muddy bed in shallow regions where the current was sluggish. Mature

specimens, 11 in number, collected from the general area around the nests, showed on examination that only males were with thick creamy-white secretion along ventral aspect which confirms the observation of Chacko and Kuriyan (1948) that onus of guarding the nests and young ones rests with the male of the species. In the Ganga River near Allahabad, the breeding pits or nests locally known as "*thālā*" are shallow saucer-shaped sandy depressions generally found in waist-deep areas about 8–12 meters from the shore where the flow is sluggish. The breeding pits in the case of *M.* (*O.*) *seenghala* are comparatively large measuring about 0·9 to 1·2 meters across and 25 to 45 cm. deep at the centre.

According to Raj (*loc. cit.*) the skin from inflamed ventral region, when sectioned, revealed the presence of villiform processes projecting from abdomen, and on the analogy of *Platystacus* of South America he interpreted these as stalks to which the eggs are attached. His work unfortunately is only in the form of an abstract and detailed observations if published would have been very useful. The typical structure of a section of skin from abdominal region of a guarding male is depicted in Fig. 5, and it is clear that the dermis with its smooth surface does not show the presence of villiform projections. As has already been stated, eggs of *M.* (*O.*) *seenghala* are small, spherical and smooth which are shed free in breeding pits where they hatch out.

The cases of parental solicitude are not uncommon among some members of Siluroidei. Interesting observations on buccal incubation have been recorded by Day (1878, p. 456) in genus *Osteogeniosus*, Jenkins (1910) in *Tachysurus jatius*, Willey (1911) in *Tachysurus falcarius* and Chidambaram (1941) in *Tachysurus jella*. It is significant to note that male of the species assumes the role of solicitous parent in these cases also. Eggert (1930) however, suggests that in *Mystus gulio*, the female may have the habit of carrying the eggs in the folds of its ventral skin. The phenomenon of oral gestation has also been recorded in some of the South American cat-fishes like *Galeichthys felis* (Lee, 1935) and *Hexanematichthys* sp. (Gill, 1905).

The breeding season of *M.* (*O.*) *seenghala* in the Ganga River is fairly prolonged; it commences from early April and extends up to end of August with cessation of summar monsoon season. While developing eggs of *M.* (*O.*) *seenghala* have been collected from the Ganga River for the first time on 29–4–1960, advanced larvæ, fry and fingerlings of both *M.* (*O.*) *seenghala* and *M.* (*O.*) *aor* have been collected regularly during the months May to August by operating spawn collection nets. Mature specimens of the two species have been encountered in the commercial landings at Allahabad during the months, March to August and both ripe and spent fish in April

to August. Khan (1934) collected ripe females of *M.* (*O.*) *seenghala* in June from the Jhelum River in the Punjab and observed that it breeds during June and July in the Punjab rivers. The breeding season of *M.* (*O.*) *seenghala* and *M.* (*O.*) *aor* in the Peninsular Rivers, however, appears to be somewhat different. Raj (1940) observed breeding of *M.* (*O.*) *seenghala* and *M.* (*O.*) *aor* in the Cauvery River in April and May. Chacko and Kuriyan (1948), on the other hand, have recorded breeding of the two species in the Tungabhadra River above Sunkesula Anicut during the months of September to December.

Summary

The embryonic and larval development of *Mystus* (*Osteobagrus*) *seenghala* (Sykes) has been described. Developing eggs of *M.* (*O.*) *seenghala* were collected from breeding pits or "*thālā*" in the River Ganga near Allahabad on 29–4–1960. Incubation period lasts about 26 hours at 23–25° C. Yolk is fully absorbed by 7th day and the larva begins to acquire general form and contours of the adult by 10th day. The developing fry subsists only on the white secretion exuded by the male who guards the nests and natural feeding activity is resorted to when the fish attains the length of 45 mm. At fingerling stage (49 to 70 mm. in length) the fish subsists mainly on insect larvæ supplemented by cladocera and is a bottom and marginal feeder. At juvenile stage (75 to 100 mm. in length) it is a column and marginal feeder subsisting on teleosts, crustaceans and insect larvæ. The breeding habits of *M.* (*O.*) *seenghala* and the interesting cases of parental care are described. The fish breeds in the River Ganga from early April to end of August.

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STUDIES ON THE PRAWN FISHERY OF COCHIN AND ALLEPPEY COAST

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Introduction

In the marine fisheries of the Indian coast prawns occupy an important position. The major portion of the marine prawn catches is from the west coast. According to Panikkar and Menon (1955) "In certain areas, especially on the west coast, the catches of prawns as a group may be more than those of any other single group of fishes". In order to obtain a clear picture of the fishery along this coast detailed study has been initiated by the Central Marine Fisheries Research Institute at a number of centres, *viz.*, Kandla, Bombay, Mangalore, Kozhikode, Cochin (Ernakulam) and Colachel. From the Ernakulam centre the middle part of Kerala coast has been covered selecting three points, Alleppey, Chellanam and Narakkal, about 22 miles apart. Alleppey situated about 35 miles south of Cochin is one of the heaviest prawn-landing centres. Here in some months of the peak season the catches at one landing centre alone has exceeded 1000 m. tons. The presence of mud banks, locally called "chakara" is one of the reasons attributed to the magnitude of the prawn fishery here. Chellanam, situated at about 14 miles south and Narakkal 8 miles north of Cochin harbour are also prawn fishing centres.

Apart from the earlier papers dealing with the fishery in general by Rai (1934), Panikkar (1937), Chopra (1939) and Srivatsa (1953), a number of papers have been published recently from the Central Marine Fisheries Research Institute on the biology and fishery of commercially important species of the country (Menon, 1953, 1954, 1955 and 1957; Panikkar and Menon, 1955 and George, 1960). In the present paper a brief account of the observation made at the three places mentioned above is presented, giving special emphasis on the recruitment of the different species and size groups of prawns into the fishery at different seasons.

Material and Methods

Preliminary observations and collection of catch statistics at Alleppey and Narakkal were commenced in 1956 and detailed study by analysis of

regular commercial catch samples brought from the three centres in 1957. Regular weekly random samples were collected from the prawn catches from the three centres and analysed. While collecting the samples no distinction was made between the catches of different types of nets. Whichever catch sample available was collected at random. In analysing each sample the percentage values of the different species based on numbers as well as on weight were determined. For plotting the length frequency curves, total length measurements from the tip of the rostrum to the end of the telson were taken after separating the two sexes. The nature of the gonads was also noted.

Methods of Fishing

The boat seine locally called "*thangu vala*" is the commonest type of net used for prawn fishing in most of the months. Only a single dug out canœ with 11–13 men in it is engaged in operating this net at Alleppey and Chellanam, whereas at Narakkal two dug out canœs with 5–6 men in each are engaged in its operation. Two other types of boat seines, namely, *vatta vala* and *koru vala*, differing mainly in size are also in use occasionally. Shore seines locally called "*kamba vala*" same as the "*kara madi*" described by Nayar (1958) are operated from the shore at Alleppey and Chellanam, mostly in the months of September to March–April. A smaller type of shore seine called *nona vala* which has not got the wings made of coir yarn like those of *kamba vala* is also used during these months. In both of these types of nets good quantities of prawns are caught along with other miscellaneous fishes. Shore seines are not operated at Narakkal. Small drag nets called *vadi vala* operated by two men near the shore are also used for prawn fishing from October–February. When shoals come very near the shore cast nets are also used, either operated from the shore or from a small boat by one or two men. However at the peak of the season in the monsoon months *thangu vala* alone is used for prawn fishing at Alleppey.

Fishing Season

The trend in landings at the three centres during the period 1956–60 is given in Tables I–VI.

In all the years the maximum catches at Alleppey are in the monsoon months, June–July in 1956–57, July–August in 1957–58, July–August in 1958–59 and September in 1959–60. The catch per man-hour also shows the same peak season. So the peak of the fishing season at this centre is between June and September. From the data for three years at Chellanam it may be said that there is no regular peak season for the fishery as such.

TABLE I

Monthly landings of prawns at Alleppey in metric tons

Year	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Total
1956–57 ..	4·53	11·97	1120·67	722·22	11·76	12·29	6·02	5·69	1·97	2·64	2·44	1·11	1903·31
1957–58 ..	3·67	7·52	54·86	403·66	391·02	70·09	3·58	12·76	2·99	2·48	1·01	0·74	954·38
1958–59 ..	1·82	60·76	13·84	225·65	323·89	22·55	5·20	7·27	0·98	0·65	1·18	3·22	667·01
1959–60 ..	1·64	1·28	55·33	21·49	19·19	94·71	63·32	1·59	0·88	2·53	1·32	1·30	264·58

TABLE II

Monthly catch per man-hour at Alleppey in g.

Year	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.
1956–57 ..	272·16	680·39	4762·72	2948·35	589·67	54·43	195·05	127·01	49·90	104·33	145·15	92·25
1957–58 ..	226·80	362·87	893·58	2299·71	3905·43	866·36	72·58	326·59	81·65	158·76	45·36	36·29
1958–59 ..	63·50	675·85	285·76	2195·39	2585·47	317·51	86·18	185·97	31·75	18·14	40·82	63·50
1959–60 ..	86·18	49·90	625·96	149·69	367·41	1374·38	966·15	13·61	13·61	68·01	40·82	77·11

TABLE III

Monthly landings of prawns at Chellanam in m. tons

Year	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Total
1957–58	.. 4·18	0·28	..	..	..	..	20·89	14·42	8·65	3·25	0·32	0·25	52·24
1958–59	.. 2·32	4·70	..	..	2·69	1·31	..	..	0·94	0·64	1·62	2·85	17·07
1959–60	.. 9·53	0·04	..	2·85	0·70	12·03	..	0·68	12·44	..	..	..	38·27

TABLE IV

Catch per man-hour at Chellanam in g.

Year	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.
1957–58 ..	.. 117·93	31·75	..	..	..	..	299·37	222·26	140·61	95·25	7·71	5·44
1958–59 ..	.. 68·04	77·11	..	..	302·55	13·61	..	..	13·61	9·07	40·82	72·58
1959–60 ..	.. 616·89	6·35	..	68·04	9·07	258·55	..	9·07	208·65	..	..	..

TABLE V

Monthly landings of prawns at Narakkal in m. tons

Year	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Total
1956–57	5·40	7·33	1·19	1·63	2·12	13·44	5·88	..	..	0·85	2·40	3·02	43·26
1957–58	0·96	9·43	..	2·27	2·57	10·39	..	..	..	0·73	..	0·69	27·04
1958–59	0·76	4·73	..	2·75	3·96	6·08	4·91	..	..	..	3·91	1·45	28·55
1959–60	10·94	6·73	3·80	1·84	1·92	0·63	10·36	..	..	1·60	3·13	2·53	43·48

TABLE VI

Catch per man-hour at Narakkal in g.

Year	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.
1956–57	317·51	952·54	99·79	72·58	72·58	498·95	213·19	..	..	13·61	154·22	58·97
1957–58	40·82	258·55	..	108·86	63·50	254·01	..	..	..	36·29	..	9·07
1958–59	45·36	66·18	..	68·04	58·97	131·54	108·86	..	..	..	68·04	136·08
1959–60	625·96	585·13	185·97	47·63	46·72	31·75	190·51	..	..	68·04	222·26	181·44

It would seem that prawns are caught along with other miscellaneous fishes as and when available. The data for 4 years at Narakkal show that the months preceding the monsoon, April and May and months following the peak of the monsoon, September and October are the months of the maximum prawn catches here. There are no prawn catches during November and December at both of the two latter centres.

Catch Composition

The important species contributing to the fishery at these centres are *Metapenæus dobsoni*, *Metapenæus affinis*, *Parapeneopsis stylifera* and *Penæus indicus*. Occasionally *Penæus carinatus*, *Metapenæus monoceros*, *Hippolysmata ensirostris* and *Leander* sp. are also present in the catches.

Metapenæus dobsoni.—This species contributes the bulk of the catches at Alleppey. During the peak especially the catches comprise mostly of this species. In 1957–58 and 1958–59 the percentage of the species steadily rose from April onwards and reached 100% and 96·4% respectively in August. During this season its percentage remains very high and goes down in November and December when the percentage of *P. stylifera* goes up. In 1957–58 when there was a good fishery of *P. stylifera* after the peak, the percentage of *M. dobsoni* dwindled to 5·5 in December. In 1958–59 and 1959–60 due to the failure of the fishery of *P. stylifera* the percentage of *M. dobsoni* did not fall so much. In 1959–60 the fishery of *M. dobsoni* during the peak period was comparatively very poor and in July–October the percentage of the species is less than 40·0 as against the high percentages noted in the previous years.

In all the three years under observation the prominent length group of the species exhibits the same changes (Fig. 1). The modal length gradually increases from 71–75 mm. in April to 96–100 mm. to 106–110 mm. at the peak. So the fishery at this time is contributed mostly by the second and third year class of prawns (Panikkar and Menon, 1955, and Menon, 1955 and 1957). In November, with the end of the main season, the larger groups completely disappear and from that month onwards (the fishery is generally poor during this period) among the prawns caught along with other miscellaneous fishes the smaller size groups dominate. From November to April–May, excepting a few bigger specimens caught occasionally, only these small-sized prawns with prominent length groups varying between 61–65 mm. and 71–75 mm. are represented in the catches. Thus the first year class (Menon, 1955 and 1957) seems to contribute the bulk of the catches in the lean months and recruitment of the older classes commences actively

in May. They dominate in the catches during the following months and go out of the fishery by November. A study of Table II shows that as far as this species is concerned with the commencement of recruitment of the

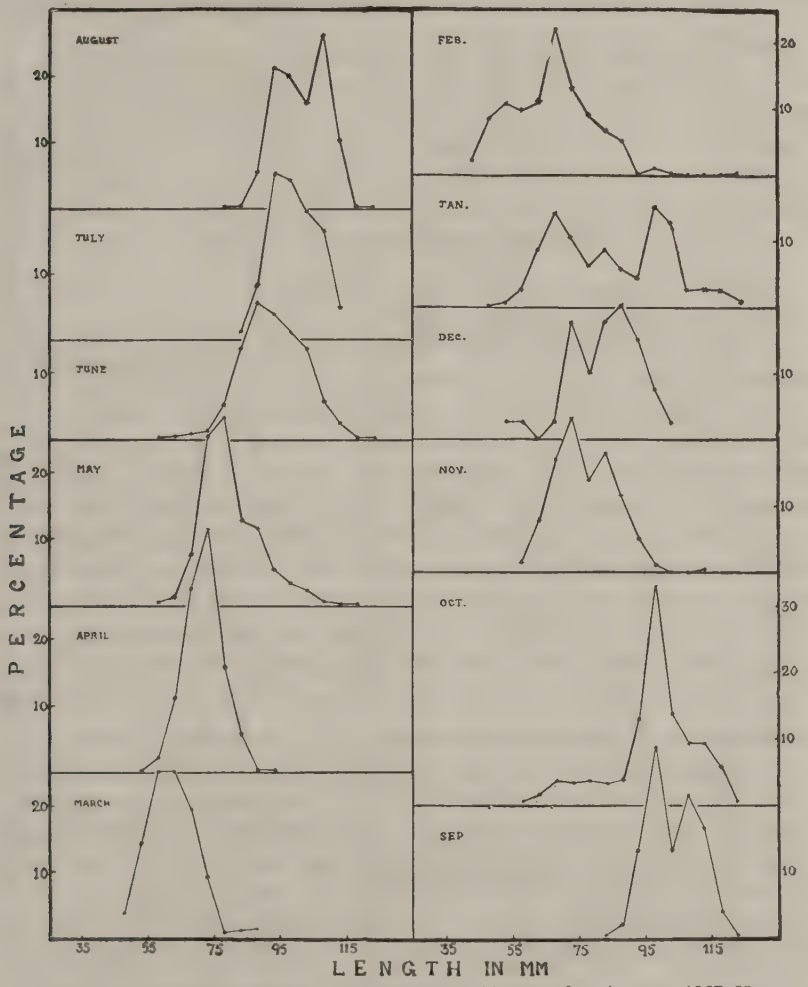

FIG. 1. Length frequencies of *M. dobsoni* at Alleppey for the year 1957–58.

older classes into the fishery from May onwards the catch per man-hour increases, thereby showing a distinct relationship between the recruit sizes and the catch per man-hour so that with the least effort maximum catches are obtained.

The study of the length frequency curves of the two sexes separately (Fig. 4) clearly shows that there is differential growth rate in the two sexes, females exhibiting a higher rate, as has been observed by Menon (1953,

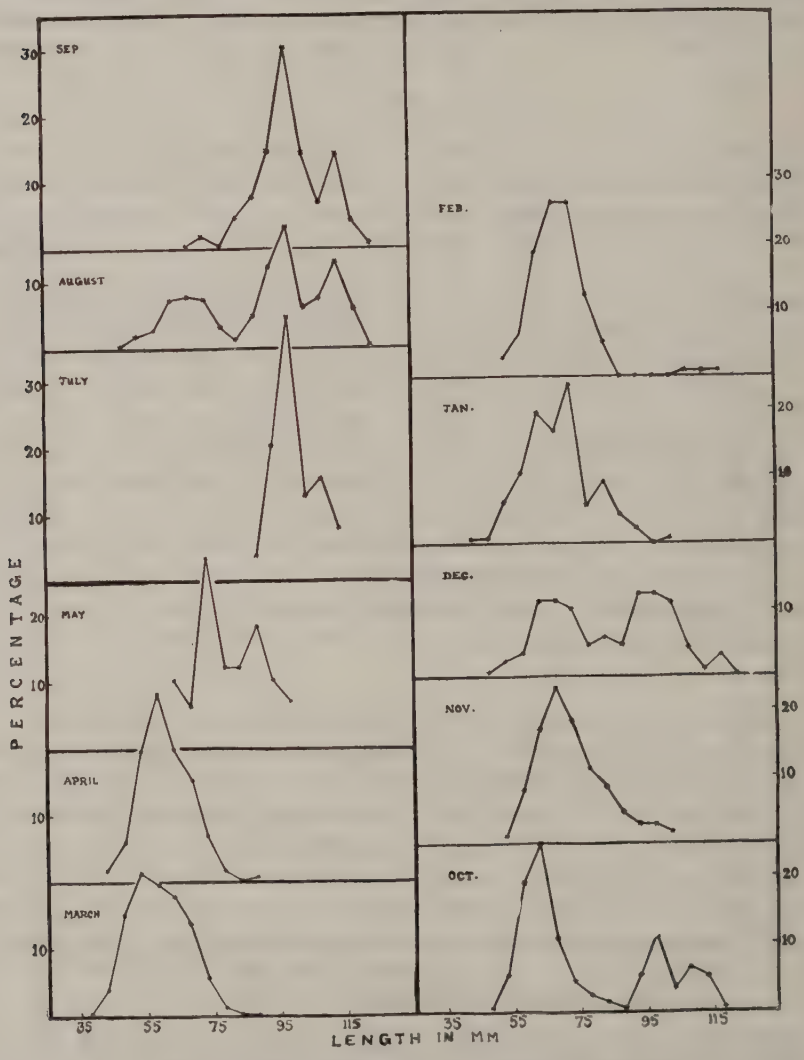

FIG. 2. Length frequencies of *M. dobsoni* at Chellanam.

1955 and 1957) and Kubo (1955). Males and females do not occur in constant proportions on these fishing grounds, the percentages of the two sexes

being very irregular in the different months (Racek, 1959 and Menon, 1955 and 1957). By noting the presence of increased numbers of mature and impregnated females in the catches the breeding season of the species could be ascertained to be more or less the same as that observed by Menon (1955), namely, May to December.

At Chellanam also *M. dobsoni* is the dominant species. In 1957–58 there was no fishing in the monsoon months and the percentage of the species is high in April and October. In 1958–59 fishing was possible during these months and 99% of the catches consisted of this species only. In the following year, as noted at Alleppey, there was a failure of the fishery of this species and hence its percentage during these months was not high except in May and September. After September it dwindles considerably.

Changes of the modal length show the same trend as at Alleppey. In all the three years in March–April the prominent length group measures 56–60 mm. and 61–65 mm. Thereafter there is a gradual increase in the modal length and in years in which length frequency data are available, in July–October the prominent length groups are at the maximum of 91–95 to 101–05 mm. After October these higher groups disappear and smaller groups again dominate (Fig. 2); but sometime after November the higher groups are also represented in the frequency curves along with the smaller groups as a secondary mode. So from November to May the first year class is mainly recruited into the fishery and in the other months the second and third year classes enter the fishery as noticed at Alleppey. A close scrutiny of the catch per man-hour for the months in which data are available (Table IV) shows that here also in the case of this species only with the recruitment of older sizes into the fishery the catch per man-hour increases.

M. dobsoni contributes to the bulk of the catches at Narakkal also, especially during the prawn season. In the three years in September the percentages of the species are 99·2, 84·9 and 68·0 respectively. In 1957–58 in the two previous months also the percentages are above 90·0. In 1958–59 during the period data are available only in September. In the last year in the two months preceding September the percentages are 70·9 and 85·6 respectively. So during the main prawn season from July–September the fishery is mostly contributed by this species. In April-June its percentage is less than 50·0.

The recruitment of the age groups into the fishery at this place is of the same pattern as at the other two places, the modal length increasing gradually from 61–65 mm. and 66–70 mm. in April to 96–100 mm. and 101–05 mm. in September–October (Fig. 3), the larger groups disappearing

from November–December and the smaller groups again becoming dominant. From November–May the first year classes are recruited and from that month onwards the second and third year classes dominate. The same relationship between the recruit sizes and the effort expended is noticed

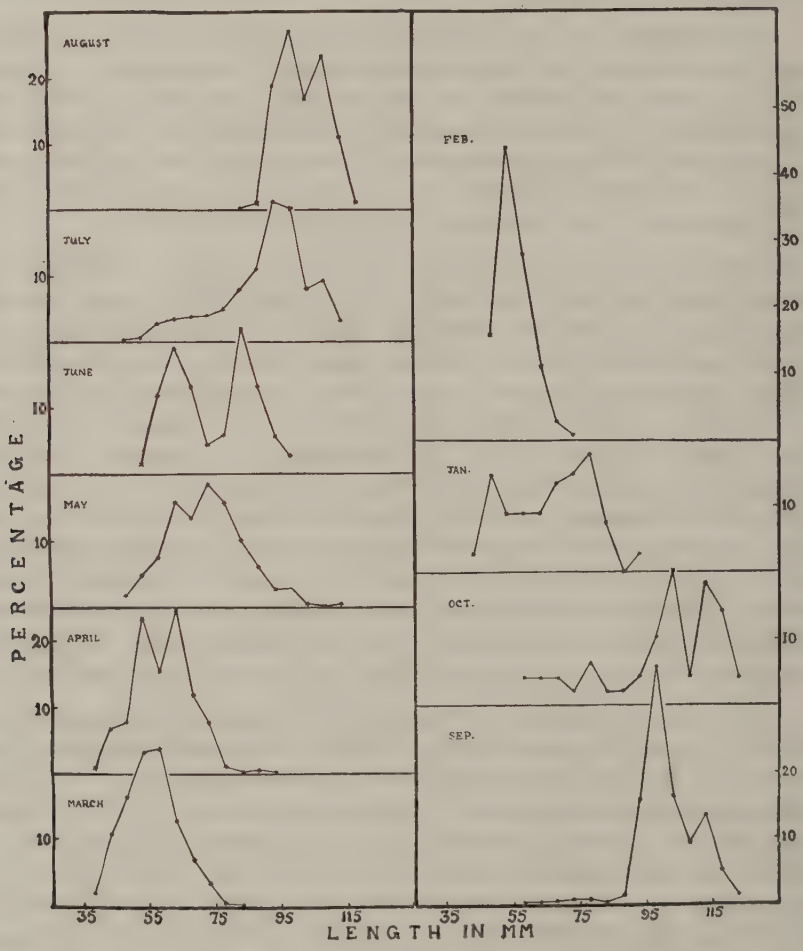

FIG. 3. Length frequencies of *M. dobsoni* at Narakkal.

here also as at the other two centres, the catch per unit effort increasing with larger sizes recruited into the fishery.

The differential rate of growth in the sexes (Fig. 4), breeding season, etc., are similar in all the three places.

Parapeneopsis stylifera.—At Alleppey this is the species next in abundance. In 1957–58 and 1958–59 during the peak of the season the percentage of this species was almost nil, the major portion of the catch being contributed by *M. dobsoni*. Generally the percentage of this species in the catches starts going up by November. In December 1957–58 the

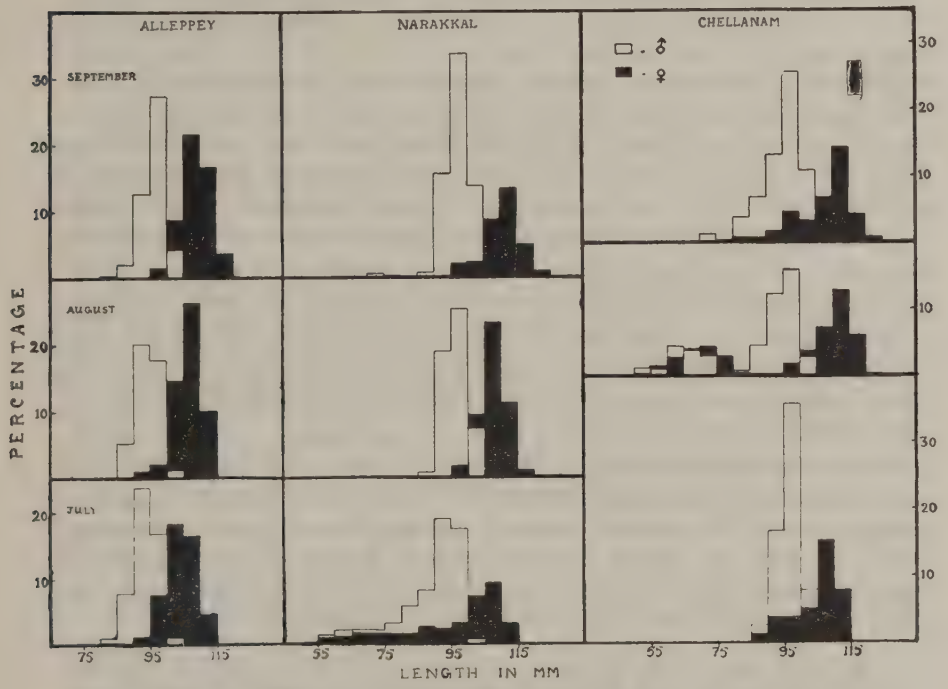

FIG. 4. Differential rate of growth in the two sexes of *M. dobsoni*.

percentage reached a record of 89·4 (80·6 by weight). In the following months also its percentages are fairly high. In 1958–59 there was a failure of the fishery of this species and hence the percentage did not rise so high during the months after November. In fact it was as low as 0·4% in November, but went up to 28·1 in December and then fell to 9·9 in January. In 1959–60, coinciding with the failure of the fishery of *M. dobsoni*, the percentage of *P. stylifera* is considerably high during the peak of the season, compared to the previous years. Its percentage in September of that year is as high as 78·8, whereas in the previous years in the same month it was almost nil. However there is a fall in the

percentage later when the species should normally show the highest values, probably due to the early exploitation.

In April and May the modal length of the species is 66–70 mm. Thereafter there is an increase in this length. During the peak of its season, *i.e.*, in January and February the prominent length groups are 81–85 mm. and 86–90 mm. In the first two years, since this species was not represented in the catches during the monsoon months it is not possible to follow the changes in the modal length in these months. But in 1959–60 it is more clear. From 66–70 mm. in April there is a gradual shifting to 81–85 mm. in August. Then that mode goes out of the picture and in September again the 66–70 mm. group becomes prominent. From then again there is a gradual shifting, reaching 81–85 mm. in January. That group disappears next month and by March-April again the smaller group becomes prominent. Thus recruitment of the younger prawns of the species into the fishery takes place twice in a year. As observed by Menon (1953) at Kozhikode the fishery of the species is contributed by prawns of the 0 year and first year classes. Although this species does not contribute to the fishery so much as to show any conspicuous relationship between the recruit sizes and the effort expended, the same trend of increased catch per man-hour with increased sizes is seen in this species also as in *M. dobsoni*.

The differential rates of growth in the two sexes have been noted here also, females showing a higher rate than males as observed by Menon (1953) at Kozhikode. The breeding season of this species at this place also agrees with that given by Menon for the species in Kozhikode waters, namely, October–December. Except in a few months in 1957–58 females were less than males during almost the entire period of observation.

At Chellanam in 1957–58 the percentage of this species started increasing from October onwards and reached the maximum of 61·5 in January with the corresponding percentage by weight 71·6. Thereafter the percentage slowly declined. In 1958–59 there was a complete failure of the fishery of this species, as noticed at Alleppey and hence in most of the months from October–March, when the species should normally show the highest values, its percentages are almost nil. In 1959–60 coinciding with the failure of the fishery of *M. dobsoni* this species appeared much early, *i.e.*, in August, dwindled in September and again increased in November. As at Alleppey the period after September appear to be the season here also for the species.

In April–May the smaller 66–70 mm. and 71–75 mm. groups are prominent in all the years. In 1957–58 from June–September length frequency curves are not available. From October up to February in most of the months it is

the 81–85 mm. group which is prominent. In 1958–59 no length frequency curves are available in most of the months due to the failure of the fishery of the species. In 1959–60 in August 86–90 mm. group is prominent. In October again it is less, being 71–75 mm., going up to 81–85 mm. and 86–90 mm. in the following months. This seems to indicate the same trend as at Alleppey, the recruitment of younger prawns taking place twice in a year and the bigger specimens after growth disappearing after August and again after February.

At Narakkal also *P. stylifera* comes next in abundance and is prominent in the post-monsoon months. In the first two years the fishery of this species seemed to have failed completely at this centre as against the failure in 1958–59 in the other two centres. In 1959–60 in October, February and March this species is predominant, percentages being 72·9, 64·0 and 62·6 respectively in these months, there being no catches in November–December.

The modal length is low in April of all the three years. In 1959–60, when regular data are available, from April onwards a regular increase in the modal length is seen, reaching 86–90 mm. in August–September. After September these larger groups disappear and again the smaller groups become dominant. In February–March the modal lengths are high and fall in April. In a few months another secondary mode also is seen in the curves, the length varying between 101–05 mm. and 106–10 mm. These might represent the second year classes (Menon, 1953 and 1957). Thus here also as in the other centres recruitment of younger specimens into the fishery occurs twice in a year.

Differential rate of growth in the sexes, breeding season, etc., are more or less the same in all the three centres.

Metapenæus affinis.—According to percentage in the commercial catches this species comes next in abundance at Alleppey, although it is not fished in very large quantities. Its highest percentage is reached in the post-monsoon months November and December. At the peak of the fishery the species is almost absent in the catches. In 1957–58 the percentage of the species was less than 7·0 in all the months, the highest percentages being in November, December, and March. Both in 1958–59 and 1959–60 the percentages are the highest in November (40·7 and 27·9 respectively by numbers and 80·0 by weight). In 1959–60 the percentage is slightly high in July also, being 17·9.

Sufficient number of specimens not being available in the samples in certain months of the year, the length frequency curves could not be plotted

for all the months regularly. But from the available curves it is clear that the prominent length groups are at the minimum length of 71–75 mm. and 81–85 mm. in February and March. Thereafter there is a regular increase in the modal length. In November and December which are the peak months for the species, the prominent length groups are also at the highest. In the three years it varies between 111–15 mm. and 136–40 mm. in these months. Afterwards these larger groups disappear. The recruitment of bigger specimens into the fishery commences in October. In January they disappear and again the smaller groups are recruited. When compared to the growth of *M. monoceros* (George, 1960) the 131–35 mm. and 136–40 mm. groups might represent the second year class. In that case the second year class is recruited into the fishery during the November–December peak of the species. So the fishery is of the first and second year classes.

The sudden increase in catch per man-hour in the month of November in certain years is mainly due to the peak of the species in the fishery and during the peak the recruit sizes are also larger, being first and second year classes, thus showing the same relationship between recruit sizes and effort expended as in other species.

Differential rate of growth between the two sexes is noted in this species also as in the case of the others. From the increased number of maturing and impregnated specimens present in the catches October–December seem to be the breeding months for the species here.

Although this species does not contribute much to the fishery at Chellanam, it is caught at this centre from October–May, with the peak between November–April. In 1957–58 the maximum percentages by number as well as weight are recorded in December–March. Both in 1958–59 and 1959–60 the highest percentage of the species is in November, being 89·5 and 43·5 respectively for the two years, with the respective percentage by weight 96·0 and 66·7. In both years an abrupt rise in the percentage is seen in July.

From the available curves, the same trend in the changes of the modal length of the species as at Alleppey is noted here also. The modal length is at the minimum of 71–75 mm. and 81–85 mm. in March–April. In November–December this length reaches 121–25 mm. and 126–30 mm. Afterwards this group disappears except in 1958–59, when the group persist for some more time reaching 131–35 mm. and disappearing in February Thus the fishery here also is contributed by the first and second year classes Recruitment of younger specimens commences after December.

At Narakkal in the first two years February and April show increased percentages for the species. In 1959–60 from January–June the percentages are fairly high, being above 15·0. So the season appears to be more or less the same as at other centres.

In 1959–60, when sufficient data are available for a few months the modal length group is at the minimum. It increases regularly and reaches 116–20 mm. in August. In subsequent months data are not enough. However in January again the smaller groups dominate, showing the same trend as at other centres.

Penæus indicus.—Even though this species is represented in the catches in certain months at Alleppey it does not contribute much to the prawn fishery. In 1957–58 it was present in the catches from December onwards, but the percentage is very low, being less than 1·0 in most of the months. In 1958–59 in July, September and October the percentages both by number as well as weight show an increase. In all the other months it is less than 1·0 or just above 1·0. In 1959–60 the percentage of the species is above 5·0 in October. It is difficult to determine the age composition of this species and also the relationship between recruit sizes and effort expended since in most of the months the number of specimens in the samples is not enough to plot length frequency curves. In 1958–59 the modal length shifts from 111–15 mm. in July to 131–35 mm. in October.

At Chellanam also the representation of this species in the catches is poor. In 1957–58 from November onwards it is represented in the catches. The percentage of 7·1 in November is the highest, with a corresponding percentage by weight of 52·8. In 1958–59 from January–March the percentage is fairly high, with the maximum of 51·3 in February with the respective percentage by weight 67·9. In March the two percentages are 34·9 and 75·0 respectively. In 1959–60 its percentage is 10·3 in September with corresponding percentage of 30·0 by weight. From the available length frequency curves from January–May the prominent length group falls between 111–15 mm. and 126–30 mm. In September–December the modes are higher, varying between 151–55 mm. and 161–65 mm. It may be roughly said that the first and second year classes are represented in the fishery.

At Narakkal the percentage of the species is very low in most of the months. In the first year its percentage is never above 3·5 in any of the months. In 1958–59 in three months in which data are available its percentage is below 10·0. In 1959–60 in June–July percentage is 22·7 and 18·0 respectively with the corresponding percentage by weight 33·3 and 22·2.

Length frequency curves could be plotted in a few months in 1959–60 only. In January–February the prominent length group is 96–100 mm. In June, July and October the prominent group ranges between 131–35 mm. and 141–45 mm.

General Remarks

Excepting for the total landings and catch per man-hour there is very great similarity between the prawn fishery at Chellanam and Narakkal with that of Alleppey. In the features of the fishery like predominant species in the catches, peak season for the different species, pattern of shifting of the modal length groups in the length frequency curves of the different species and recruitment of different age groups into the fishery and their relationship with effort expended, etc., there is great resemblance. At Alleppey the peak season fishery is contributed by the second and third year classes of *M. dobsoni*. Only the first year classes are recruited into the fishery during December–May. The recruitment of the second and third year classes commences in May. They contribute to the peak season fishery in the following months and disappear by November. There is a direct relationship between the recruit sizes of this species into the fishery and the catch per man-hour. In the case of *P. stylifera* recruitment of younger prawns of the first year class takes place twice in a year, after February and after August and the fishery is mostly of the 0 and first year classes. The second year classes also come into the fishery in a few months. The peak season of the fishery of this species is January-February. The peak season for the species *M. affinis* is November-December and the fishery is mostly of the first and second year classes. Recruitment of the bigger specimens of the second year class commences after October. So the peak season for the species is mostly contributed by the second year class. After January again the smaller first year class commences. During the peak season of both *P. stylifera* and *M. affinis* more or less the same trend of increased catches per man-hour with increased recruit sizes into the fishery as in the case of *M. dobsoni* is noticed. The same pattern of recruitment of these three species is seen in both the other centres. All the three centres being located on the same coast, about 22 miles apart, and fishing done by more or less the same type of nets and the fishery supported by probably specimens from the same spawning ground, this sort of similar pattern in the recruitment of the different species, the shifting of the modal length groups and the relationship of the recruit sizes and the effort expended could be expected.

In the matter of total prawn landings there is very great difference between the centres, the landings at Alleppey being much higher than the

other two centres. Among the three places the mud bank is located at Alleppey only. So it is but natural to conclude that the mud bank has got an influence on the total landings of prawns. Reporting on the phosphate content of the mud banks of Kozhikode area Seshappa (1953) has commented that "it appears highly probable that the well-marked seasonal features in the biology of the inshore area along this coast are closely related among other factors to the existence of these extensive mud banks". With a view to find out whether there is any correlation between some of the hydrological features of the mud bank area and the prawn landings some data were collected during 1956–57. For comparison, the same data were collected from Narakkal also and these are given in Table VII and Fig. 5.

The average monthly data for one year show that in June-July when there is maximum prawn landings in that year at Alleppey the dissolved oxygen content of the water is very low whereas at Narakkal where the catch is very poor at that time comparatively the dissolved oxygen is at the highest. The salinity at Alleppey even during the monsoon months never declines below 31·00‰ whereas at Narakkal in the monsoon months it goes down very much, as low as 12·03‰ and 13·45‰ in June and July respectively. Surface temperature shows that during the monsoon months the surface water at Alleppey is cooler than that at Narakkal. pH is low at both places during the monsoon months; but at Narakkal it is slightly lower than at Alleppey. Thus comparing the results of the two places for one year, at the mud bank area at Alleppey along with the maximum prawn landings in the monsoon months decreased oxygen content and temperature and higher salinity and pH are noticed. Although it seems justifiable to conclude that these factors have an influence of improving the prawn fishery at Alleppey more work on these lines is needed to arrive at a definite conclusion. In American waters disappearance of prawns with increased temperature has been noted by several authors. According to Anderson (1955) "it seems that the shrimps (sub-adults) are rather insensitive to large fluctuations in salinity but that they are quite sensitive to small changes in temperature".

Another factor which seems to influence the prawn landings at Alleppey is the comparatively calm nature of the sea during the monsoon months in the mud bank area. Because of heavy rains and stormy sea during the height of the monsoon boats cannot be operated both at Narakkal and Chellanam. But at Alleppey at this time the water above the mud bank is comparatively calmer and hence fishing operations are possible. In fact because of this most of the boats belonging to villages situated in a radius of up to 25 or even more miles gather there during the monsoon period and with the increased fishing operations prawn landings also increase.

TABLE VII

Hydrological features of the sea-water at Alleppey and Narakkal for 1956–57

Month	Alleppey				Narakkal			
	Dissolved oxygen c.c./litre	Salinity ‰	Surface temperature °C.	pH	Dissolved oxygen c.c./litre	Salinity ‰	Surface temperature ° C.	pH
1956								
May	3·04	33·83	29·9	..	3·16	31·89	28·7	8·30
June	3·01	31·71	26·5	8·20	4·73	12·03	28·7	8·15
July	2·29	34·55	27·9	8·23	4·50	13·45	29·1	8·17
August	4·25	31·57	26·9	8·17	3·98	19·07	26·6	8·13
September ..	4·06	33·74	26·1	8·30	4·66	28·09	27·8	8·31
October	4·72	31·80	27·3	8·40	4·33	32·25	29·1	8·38
November ..	2·35	34·60	29·0	8·25	4·06	32·07	30·0	8·33
December ..	4·82	33·79	29·5	8·35	4·09	33·16	28·9	8·35
1957								
January	3·25	33·97	28·0	8·30	3·66	33·33	28·8	8·35
February.. ..	3·79	34·06	29·5	8·35	3·59	33·69	30·5	8·38
March	3·72	34·33	30·5	8·38	3·72	34·33	31·0	8·40
April	3·21	34·06	31·3	8·40	4·23	35·50	31·8	8·38

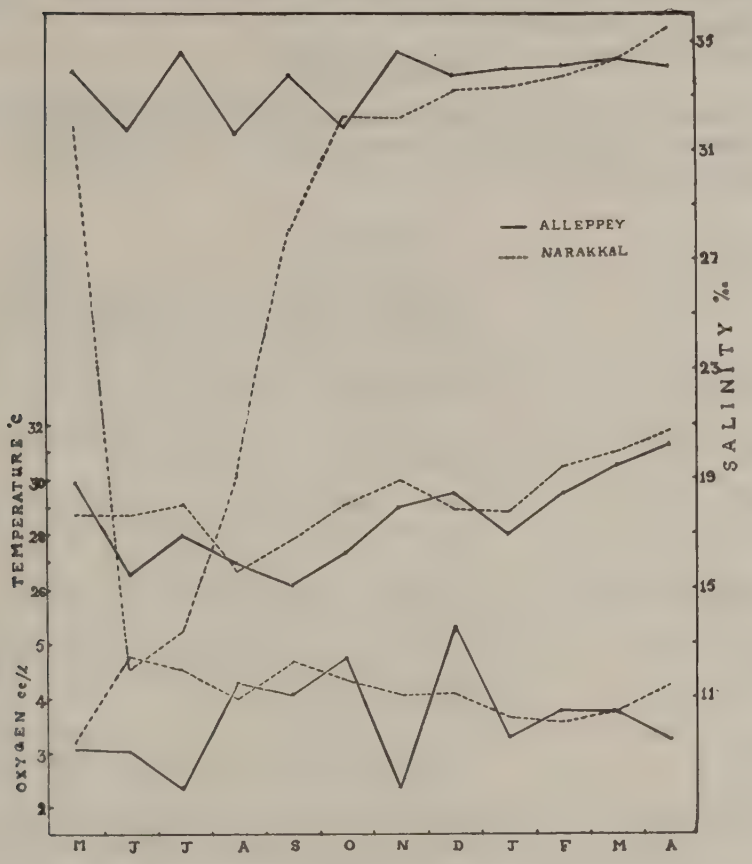

FIG. 5. Salinity, surface temperature and dissolved oxygen of the sea-water at Alleppey and Narakkal coast during 1956–57.

SUMMARY

The monthly prawn landings at the landing places Alleppey and Narakkal for 4 years and Chellanam for 3 years are given. Although the total catch of prawns at Narakkal and Chellanam differ much from that at Alleppey, the composition of the catches, the season for the different species, and the recruitment of the different species into the fishery are more or less the same at all the three places. These features of the fishery are described giving special emphasis on recruitment. A direct relationship between the recruit sizes and catch per man-hour is noticed.

The probable influence of the mud bank on the increased prawn landings at Alleppey is discussed.

Acknowledgement

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OBSERVATIONS ON THE BIOLOGY OF *RACONDA RUSSELLIANA* (GRAY)

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Introduction

Raconda russelliana (Gray) is a medium-sized clupeid fish found in the 'Bay of Bengal to the Malay Archipelago' (Day, 1878). It is commonly present in the catches from the mouth and fore-shore areas of the Hooghly estuary. However, in this region fishing operations are restricted to the winter months (mid-November to mid-February), for during other months fishing is practically impossible due to rough weather conditions. The fish caught are generally sun-dried and consumed mostly by people of the low income group.

R. russelliana is the only species of the genus recorded so far from India. In view of the fact that fluctuations in its fishery have been observed during different years, it was thought worthwhile to make investigations on the biology of the species and the present account is based on data collected during the winter seasons of 1956–60.

Material and Methods

The specimens used for this study were obtained from bag-net (*Behundijal* or *Beenjal*) catches at fortnightly intervals. Fish measuring up to 245 mm. in total length could be obtained, although it has been reported earlier that the species grows to a maximum length of about 200 mm. only (Weber and Beaufort, 1922). In all cases the samples were preserved in 5% formaldehyde solution immediately after collection. Since the caudal fins of many of the specimens collected during the later years were found to be mutilated, standard lengths only were taken into consideration for all the studies excepting for length frequency observations where the total lengths of 1,751 specimens collected during 1956–57 could be measured. However, both total and standard lengths of a few specimens were measured to examine the relationship between the two. All length measurements, correct to the nearest millimeter, were taken on a fish measuring-board. A trip-pan balance was used to measure the weight correct to the nearest milligram. All the samples examined consisted of female specimens only.

In order to determine the abundance of various food items in the diet of the fish, eye estimation (Pillay, 1952) was found to be the best practicable method.

Spawning periodicity was determined by ova diameter studies. The diameters of 4,000 ova from 13 specimens in V stage of maturity and varying in length from 156–185 mm. were measured, using an ocular micrometer and following the method employed by Clark (1934). One micrometer division was found to be equivalent to $13 \cdot 535 \mu$.

For fecundity studies, ovaries in IV and V stages were treated with Gilson's fluid modified by doubling the amount of acetic acid (Simpson, 1951). Since the fish had already been preserved in formaldehyde, this fluid was not fully effective as found by Simpson (*op. cit.*). However, the treatment softened the ovaries to a considerable extent and the eggs could be liberated easily with the help of a camel-hair brush. The entire ovary, after the removal of adhering moisture with a blotting-paper, was weighed in a physical balance with a sensitivity of 0·01 gm. In each case a sample of 0·2 g. was weighed out from the right and left ovaries and the ova counted, from which value the total number of ova in each ovary was computed. In order to test the dependability of this method, entire counts were made in 10 cases and the percentages of error was found to be only 2·68, 4·71, 7·58, 7·84, 9·34, 10·24, 10·42, 10·71, 12·08 and 14·1 over estimate.

The maturity stages mentioned correspond to the scale adopted by the International Council for the Exploration of the Sea (Wood, 1930).

Total length-standard length relationship.—The total and standard lengths of the complete specimens, ranging from 172–221 mm. in total length, have been plotted as a scatter diagram (Fig. 1) with a view to find out the relationship between the two measurements. From the figure it will be seen that all the points lie about a straight line, the regression line, which is fitted into the diagram by the method of least squares. The relationship between the standard length, Y, and the total length, X, may be expressed as:—

$$Y = 1 \cdot 0646 + 0 \cdot 8227 X.$$

The correlation coefficient, '*r*', is calculated to be 0·9829, showing a high degree of correlation between the two lengths.

Length frequency distribution.—Length frequency histograms (Fig. 2) made with the measurements of 1,751 specimens varying in length between 71 and 245 mm. shows the presence of two distinct modes, one at 163 mm. and another at 203 mm. However, a dissection of this apparently bimodal

curve (Harding, 1949) revealed a possibility of the histograms being composed of six different normal curves with modes at 88 mm., 138 mm., 163 mm. 183 mm., 203 mm. and 233 mm. Since *R. russelliana* has only an annual

FIG. 1. Relationship between total and standard length of *R. russelliana*.

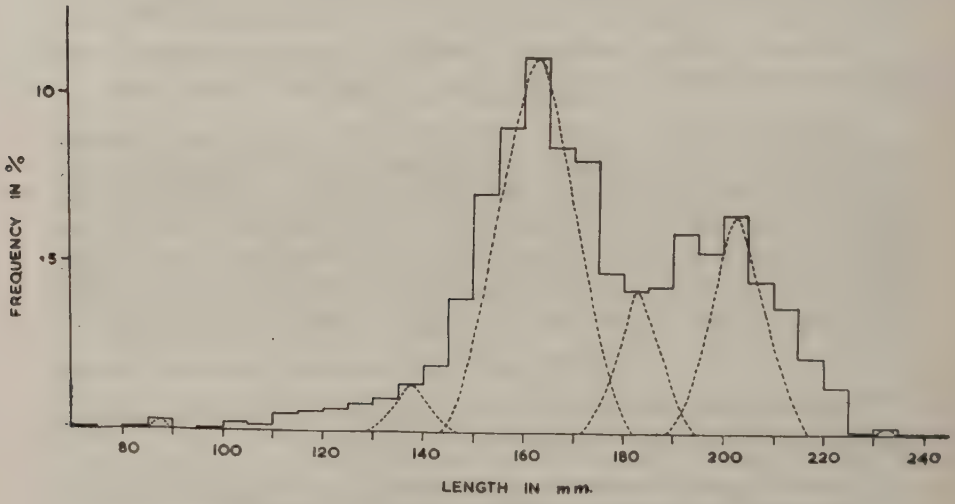

FIG. 2. Length distribution of *R. russelliana* during the fishing season of 1956-57.

restricted spawning season, it is probable that the modes represent the mean values of the age groups.

Length–weight relationship.—Length–weight relationship of *R. russelliana* ranging in length from 33–193 mm., was studied. The fish were grouped into 5 mm. range length classes and when the average weights were plotted against the mid-points of the length groups, a parabola was obtained. A logarithmic graph (Fig. 3) prepared from the above data shows a clear straight-line relationship.

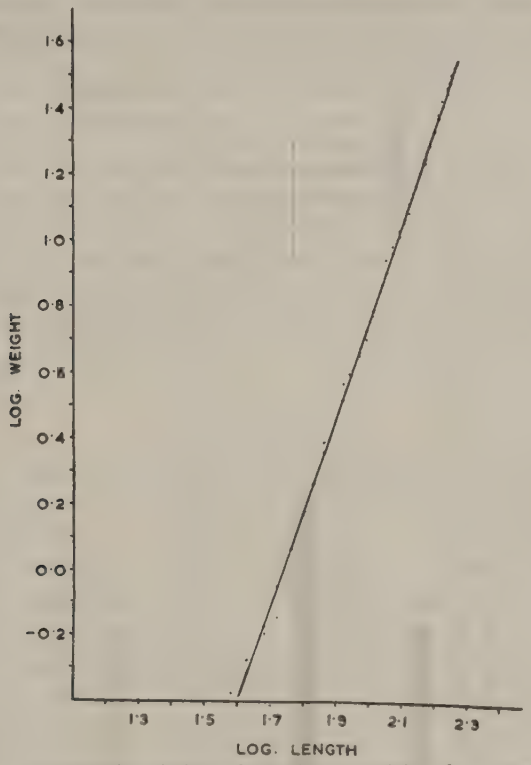

FIG. 3. Logarithmic relation of length and weight of *R. russelliana.*

The length-weight relationship of the species, determined by the general formula $W = CL^n$ or in its logarithmic form $\log W = C + n \log L$, where W = the weight of the fish in grams; L = standard length in millimetre and C and n = constants, is expressed as follows:—

$$\log W = 2{\cdot}8965 \log L - 5{\cdot}0513$$

or

$$W = 0{\cdot}000008886\ L^{2{\cdot}8965}$$

The correlation coefficient, '*r*', is calculated as 0·9989 indicating a very high degree of correlation.

Food and Feeding Habits

Stomach contents of *R. russelliana* collected during the winter months of 1959–60 were analysed in detail to study the food and feeding habits of the species. Even though all the specimens had been preserved in formaldehyde solution it could be ascertained from the total stomach contents

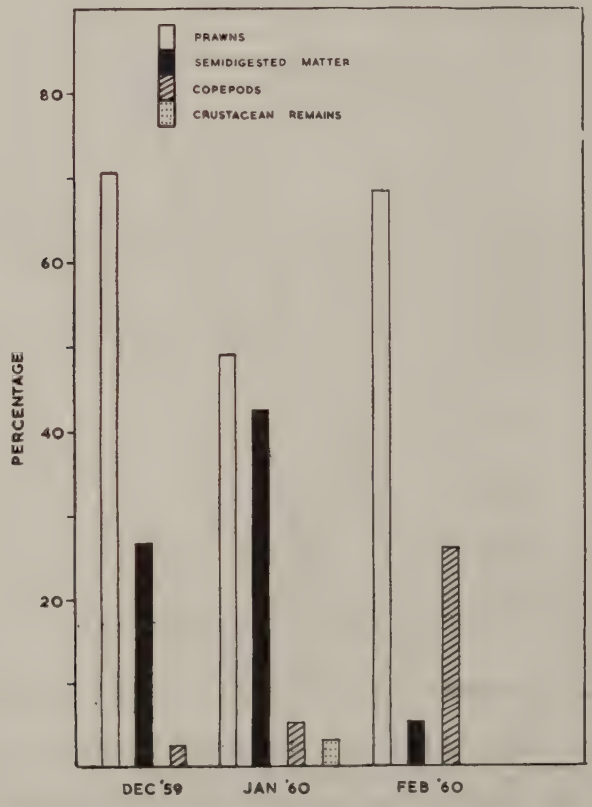

Fig. 4. Histograms showing the variations in food of *R. russelliana* during 1959–60 fishing season.

that there was no likelihood of any loss having taken place due to vomiting at the time of capture or during preservation, as has been noticed in the case of certain other fishes (*see* Pillay, 1952).

The percentage values of the main constituents of the stomach contents, *viz.*, larvæ and juveniles of prawns, copepods, other crustacean remains and semi-digested matter, obtained for all the three months, have been plotted as histograms in Fig. 4. The fish appears to be a surface feeder and from the figure it will be seen that prawns constitute the most important food item, young ones of *Acetes* spp. being the most predominant. Young and juvenile fish appear to consume more of copepods. Considerable amount of semi-digested matter was present in many of the stomachs examined, but it could be noticed that most of these were of crustacean origin. Very occasional presence of teleostian tissue and diatoms was also noticed, but these were in negligible proportions only.

The condition of feed was determined from the degree of distension of the stomach and the same has been classified as 'gorged', 'full', '$\frac{3}{4}$ full', '$\frac{1}{2}$ full', '$\frac{1}{4}$ full', 'trace' and 'empty'. The percentages obtained in each of these groups for the three months under study are presented in Table I. It is obvious that the feeding intensity of the fish is appreciably high, a good number of stomachs being either in 'gorged' or 'full' conditions. The few empty stomachs (9·4%) observed were from specimens collected during January only.

TABLE I

Condition of feed (in percentages) of R. russelliana *during the three months*

	Gorged	Full	$\frac{3}{4}$ Full	$\frac{1}{2}$ Full	$\frac{1}{4}$ Full	Trace	Empty
December ..	31·7	19·5	17·1	14·6	7·3	9·8	
January ..	9·4	20·3	17·6	17·6	13·5	12·2	9·4
February ..	17·9	51·3	17·9	5·1	5·1	2·7	

SPAWNING

As mentioned earlier, only female specimens of the fish were present in the catches and all collected during the fishing season of 1959–60 were in the IV, V or VI stages of maturity. The diameter of the ovarian eggs varied from 2 m.d. (micrometer division) to 64 m.d. (1 m.d. = 13·535 μ). Among these, the ones with either the peripheral zone or the entire body transparent (V and VI stages) had a diameter range of 41 to 64 m.d. Ova measuring 25 to 40 m.d. were opaque and fully yolked and hence

they were placed in IV stage. III stage ova present were partly yolked and varied in diameter from 13 to 24 m.d. In those which measured 6 to 12 m.d. yolk formation had just commenced and so were considered to be in II stage. Ova smaller than 6 m.d. in diameter were taken as I stage.

In order to determine the frequency distribution of the eggs in the ovary, the diameters were divided into 5 m.d. groups. Separate polygons drawn for individual fishes in the same stage of maturity showed no difference in the ova-diameter frequency, thereby indicating the absence of any variation in the spawning periodicity between individuals. So a single polygon was made using the entire data (Fig. 5). From this figure it will be seen that

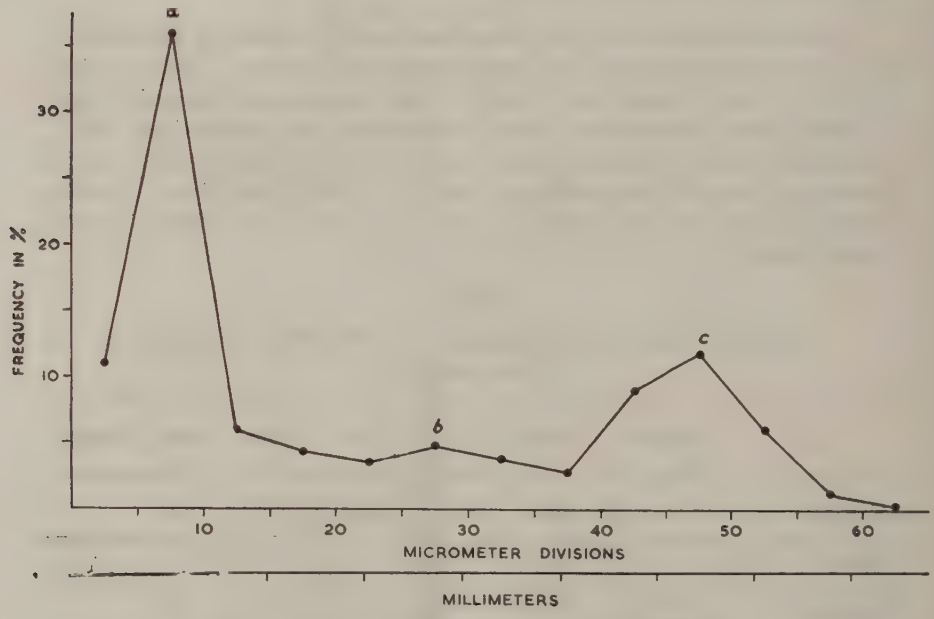

FIG. 5. Frequency distribution of ova in *R. russelliana*.

ripe ova ranging in diameter from 25 to 64 m.d. are well represented in the ovary. Mode '*a*' indicates the recruitment stock which is usually present in the ovary throughout the year. Modes '*b*' and '*c*' are completely cut off from mode '*a*'. It is likely that the ova ranging in size from 25 to 64 m.d. are the stock of eggs to be shed during the next spawning season. The absence of an intermediate mode between '*a*' and '*b*' indicates that there is no withdrawal of eggs from the recruitment stock to undergo maturation by the time the mature eggs at modes '*b*' and '*c*' are spawned. It is generally known

that the spawning period of a fish will be short and definite if the mature eggs are sharply separated from the stock of immature eggs (Hickling and Rutenberg, 1936). The spawning of *R. russelliana* seems to be restricted to a particular period. Since the diameter of the eggs of the spawning stock varies from 25 to 64 m.d., the duration of this period appears to be not very short. Supporting evidence is obtained from the availability of ripe females in the catches throughout the three months.

It is interesting to observe that no spent fish could be collected during the entire period of study. So, it is presumed that the breeding ground of the fish is far away from the inshore areas. In this connection it would be of interest to mention that larval stages of *R. russelliana* have also not been recorded in the regular tow-net collections made from the inshore regions.

The absence of males of *R. russelliana* in the samples obtained may presumably be due to (1) differential vertical distribution of the two sexes, (2) gear selectivity, or (3) early spawning migration of the males. Similar instances of occurrence of females alone in some samples of *M. parsia* has been recorded by Sarojini (1957) who attributed the condition to an early migration of males into the off-shore spawning grounds.

Fecundity

The reproductive capacity of a fish is determined by the number of eggs shed in each spawning season (Pillay, 1954) and it is well known that a knowledge of fecundity is necessary for fishery investigations. 84 ovaries of *R. russelliana*, ranging in length from 124 to 189 mm., were studied in order to find out the number of eggs spawned and its relationship with the length and weight of the fish. The fecundity varied from 1194 to 7971. In Figs. 6 and 7, the fecundity values are plotted as scatter diagrams against the length and weight respectively. For establishing the relationship, the data were grouped into 5 mm. length and 2 g. weight ranges. The average fecundity value for each length or weight group is taken to represent the mid-point of the range. Although the values for individual fish in the different groups varied considerably, definite relationships between the fecundity and length/weight could be established.

The relationship for length and fecundity may be expressed as:

$$F = 0{\cdot}1738\ L^{3{\cdot}6227}$$

or in logarithmic form, $\log F = 3{\cdot}6227 \log L - 0{\cdot}7595$ where F is the fecundity and L is the standard length of the fish in mm.

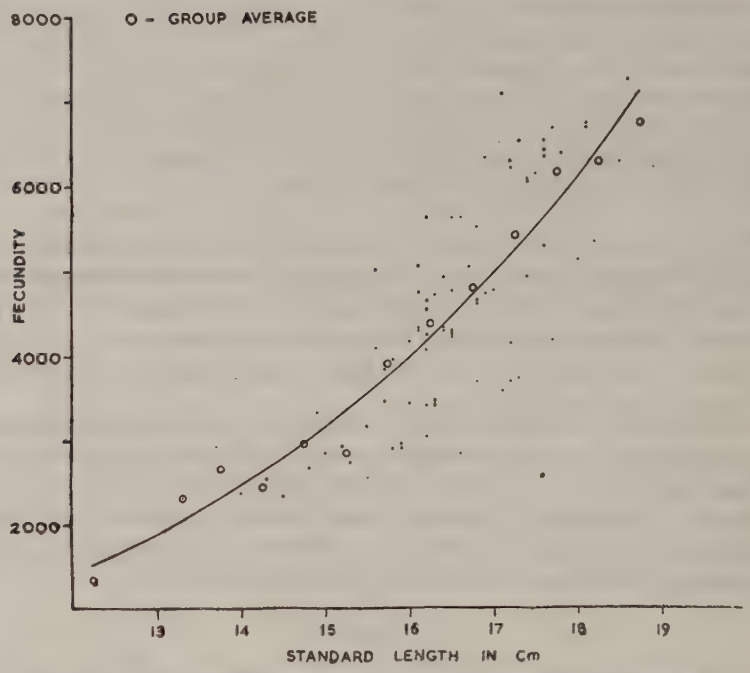

FIG. 6. The relation between length and fecundity of *R. russelliana.*

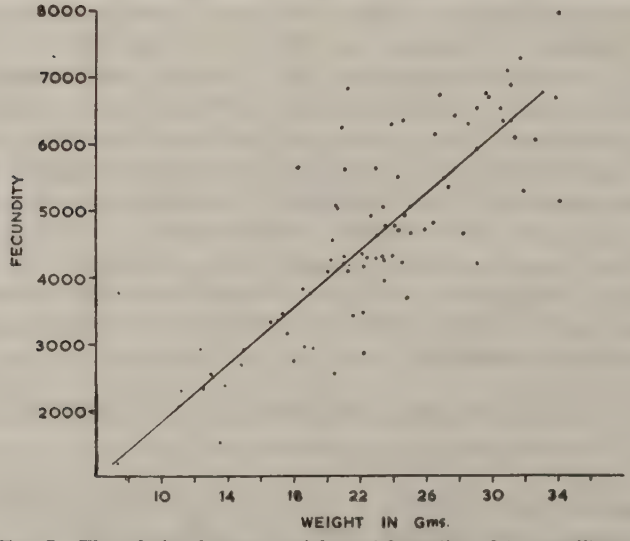

FIG. 7. The relation between weight and fecundity of *R. russelliana.*

The weight-fecundity relationship may be expressed as:

$$F = 213 \cdot 696\, W - 715 \cdot 5816$$

where F is the fecundity and W is the weight of the fish in grams.

The values of correlation coefficient, '*r*', were calculated to be 0·9822 and 0·9913 respectively indicating significant relationships.

In *R. russelliana*, the fecundity values yielded curve and straight line relationships when plotted against the length and weight respectively. It is seen from the equation that the fecundity of the species increases at a rate slightly higher than the cube of its length. Various relationships have been established for fecundity and length of different fishes by earlier workers. Clark (1934) found that the number of ova produced by individual sardines increases as the square of its length. The fecundity of Plaice has been shown to be related to the cube of its length (Simpson, 1951). In long rough dab it increases at a rate slightly higher than the cube of its length (Bagenal, 1957).

Summary

Raconda russelliana is quite common in the commercial catches of lower Sunderbans where the fishery is exploited during the winter season only, due to unfavourable weather conditions during other periods.

A relationship has been established between the standard and total lengths.

The data obtained during 1956–57 revealed that the length of the fish caught ranges from 71 to 245 mm. (total length) and also the probable presence of six age groups.

The length-weight relationship of the species is in the form of a parabola and a formula has been worked out for the same.

R. russelliana is found to be an intensive surface feeder feeding mainly on young *Acetes* spp.

The spawning period of the fish appears to be restricted and the fecundity has been found to have a curve relationship with the standard length and a straight line relationship with the weight of the fish.

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NOTES ON EGGS, LARVAE AND JUVENILES OF FISHES FROM INDIAN WATERS

VIII. *Scomberomorus guttatus* (Bloch and Schneider), IX. *Scomberomorus commerson* (Lacépède) and X. *Scomberomorus lineolatus* (Cuvier)

By S. Jones

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VIII. *Scomberomorus guttatus* (Bloch and Schneider)

This is the commonest seerfish in Indian waters and is fairly widely distributed in the Indo-Pacific from the Persian Gulf in the east to the Western Pacific from Taiwan to Indonesia. It attains a length of about $\frac{3}{4}$ of a metre. According to Munro (1943) *S. guttatus* does not occur in Australian waters and the specimens formerly identified as *S. guttatus* were most likely either *S. queenslandicus* or *S. semifasciatus*. Some may even refer to *S. niphonius*.

The only information we have on the developmental stages of *S. guttatus* is by Delsman (1931) and Vijayaraghavan (1955). The former had collected three sets of eggs from three places, *viz.*, Kumai in Borneo, Amphitrite Bay in Sumatra and Cheribon in Java and had adduced reasons for considering them as those of *Cybium* (= *Scomberomorus*) and at least one of them as those of *Cybium guttatum* (= *S. guttatus*). Though descriptions and figures of the three types of eggs and the larvae that hatched out from them have been given by Delsman (*op. cit.*) there has been no attempt subsequently on the part of anyone to check or confirm his provisional identification and unfortunately it would appear that the tendency has been to consider his inference as final though he never wanted them to be taken so. None of the eggs could be of *S. commerson* since their characters do not agree with the eggs of this species given by Munro (1942) who had artificially fertilized them and studied their development up to the prolarval stage. In view of the difference in the alignment of the chromatophores in the embryos and larvae described by Delsman it is almost certain that the eggs collected by him from Indonesian waters belong to three different species. If it is presumed that the general appearance of the early larvae of *S. commerson* and *S. guttatus* could be more or less similar, the chances are that none of the eggs referred to by Delsman could be considered as belonging to the latter also.

Large numbers of late larval and juvenile specimens of *Scomberomorus guttatus* are caught along with *S. commerson* in shore seines during February to May along the South Kerala coast and the specimens described in this account are mostly from Vizhingam near Trivandrum. Juvenile specimens from Madras and Waltair were also examined in the course of this study and no significant differences were noticed between them. The smallest specimen in the collection was about 16 mm. in total length and a connected series consisting of hundreds of specimens up to a length of about 75 mm. were available for examination. Detailed measurements of a selected number of specimens are given in Table I. Alizarin preparations were made to study the vertebral counts and other skeletal characters for the confirmation of the species and to distinguish it from *S. commerson*. While *S. guttatus* has 48–49 vertebræ + urostyle, *S. commerson* has 43–44 + urostyle. The former has a comparatively shorter head, a less pointed snout and a deeper body than the latter. The head length to standard length relationship in the early juveniles of the two species is given in Fig. 1. Further the teeth are comparatively small in *S. guttatus* whereas they are larger in *S. commerson*. In the younger specimens studied the size of the pre-opercular spines get progressively reduced from above to below and none extends beyond the operculum in *S. guttatus*, whereas in the corresponding stages in *S. commerson* the second spine situated at the angle of the pre-opercule is conspicuously larger than the rest and extend beyond the operculum. In older specimens with the distinct adult characters there is hardly any difficulty in distinguishing the species. The only possibility is that stages of *S. guttatus* could be confused with *S. lineolatus* between which there is some superficial resemblance. The latter has 49 or 50 vertebræ.

14·8 *mm.** *Stage* (Fig. 2).—The head is 2·7 and height 4·3 in standard length. Most of the larval characters are lost except the preopercular spines of which the uppermost is the largest. Teeth are present and these are comparatively smaller-sized than those in the corresponding stage in *S. commerson*. All the fins have their full complement of rays and spines but the membranous connection between the finlets still persists. The general colouration is white in formalin and chromatophores are distributed as shown in the figure. On the head they are present in patches at the tip of the snout, above and below the orbitals, above the region of the hind brain and on the posterior region of the opercle. On the body they are present close to the base of the dorsal fin, and along the mid-lateral line and a few

* Unless otherwise mentioned all lengths given are standard length.

TABLE I

Measurements of Scomberomorus guttatus (*Bloch and Schneider*) *in mm.*

Sl. No.	Place and date of collection	Standard length	Head	Snout	Eye	Maxilla	Sn. to 1st D.	Sn. to Anal	1st dorsal spine	Depth at 1st dorsal origin	Gill rakers
1*	V. 16-3-1959	14·76	4·50	2·15	1·52	3·14	5·50	8·73	0·96	2·93	..
2	do.	15·04	5·40	2·19	1·57	3·45	6·21	10·15	1·15	3·62	..
3	do.	16·64	5·64	2·19	1·62	3·56	6·24	10·37	1·10	3·92	..
4	do.	17·85	6·19	2·40	1·68	3·61	6·80	11·42	1·20	3·80	..
5	do.	18·74	6·75	2·56	1·83	4·01	7·17	12·13	1·41	4·10	..
6	do.	19·22	6·91	2·77	1·88	4·02	7·32	12·46	1·36	4·18	..
7	V. 11-3-1959	19·84	6·85	2·56	1·88	4·13	7·29	12·64	1·41	4·18	..
8	do.	20·06	7·17	2·82	1·95	4·50	7·64	13·19	1·41	4·56	..
9	do.	21·20	7·20	2·66	1·89	4·38	7·75	13·61	1·41	4·49	..
10	do.	22·72	7·70	2·93	2·04	4·71	7·68	14·07	1·57	5·18	..
11*	V. 27-2-1959	22·90	7·70	2·85	1·94	4·71	8·10	14·28	1·80	5·10	0+3
12	do.	25·00	8·40	3·00	2·20	5·00	9·20	16·50	2·10	5·50	0+4
13	do.	28·00	8·70	3·00	2·20	5·30	9·50	19·00	2·30	6·00	1+5
14	do.	30·70	9·60	3·60	2·20	5·60	10·50	19·50	2·50	6·40	0+5
15	V. 1-5-1959	35·00	10·70	4·00	2·40	6·10	12·00	21·20	2·90	7·10	2+5
16	do.	38·50	12·20	4·20	2·80	6·20	13·00	24·50	2·80	7·70	1+5
17*	do.	41·20	12·60	5·20	2·90	6·50	13·30	26·50	3·00	8·20	1+4
18	do.	45·00	12·40	5·10	3·00	6·80	13·70	28·10	3·00	8·90	2+5
19	W. 28-2-1958	49·00	14·00	5·00	3·00	7·70	14·90	30·50	3·90	10·30	1+4
20	do.	51·50	13·40	5·00	3·20	7·70	15·80	31·80	3·90	10·60	2+6
21*	W. 25-2-1959	66·80	16·90	5·80	3·60	9·40	18·80	38·30	5·00	14·60	2+5
22	do.	75·50	19·50	6·80	4·20	10·70	21·20	44·20	5·80	16·80	2+7
23	do.	83·50	21·20	7·00	4·50	11·20	23·70	49·50	6·00	19·00	2+6
24	V. 4-3-1959	228·50	48·00	17·00	8·40	26·70	57·40	125·00	12·60	44·00	3+7
25*	do.	239·00	48·80	17·20	8·90	26·80	58·20	127·00	12·80	44·50	3+8

* Denotes specimens described and figured. V. = Vizhingam. W. = Waltair (collected by Mr. K. Srinivasa Rao).

at the base of the caudal and anal fins. The anterior region of the first dorsal is slightly pigmented.

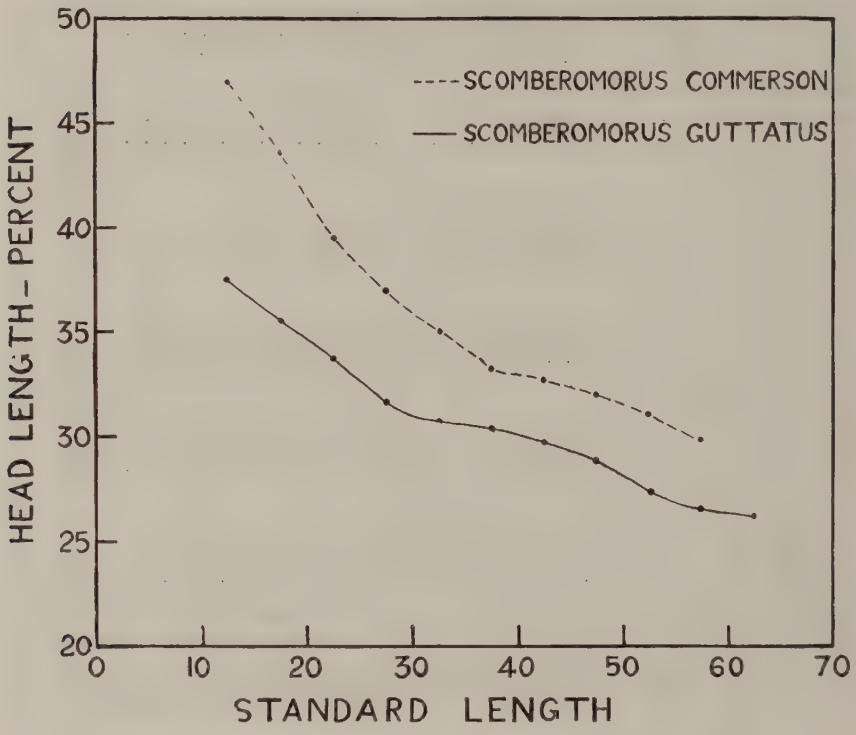


FIG. 1. Percentage of head length against standard length in mm.

FIG. 2. *Scomberomorus guttatus*, 14·8 mm. long.

22·9 *mm. Stage* (Fig. 3).—The head is 3 and height 4·5 in standard length. Except for the slight increase in the depth and length of the body

there is very little difference from the earlier stage. Chromatophores have slightly increased in number.

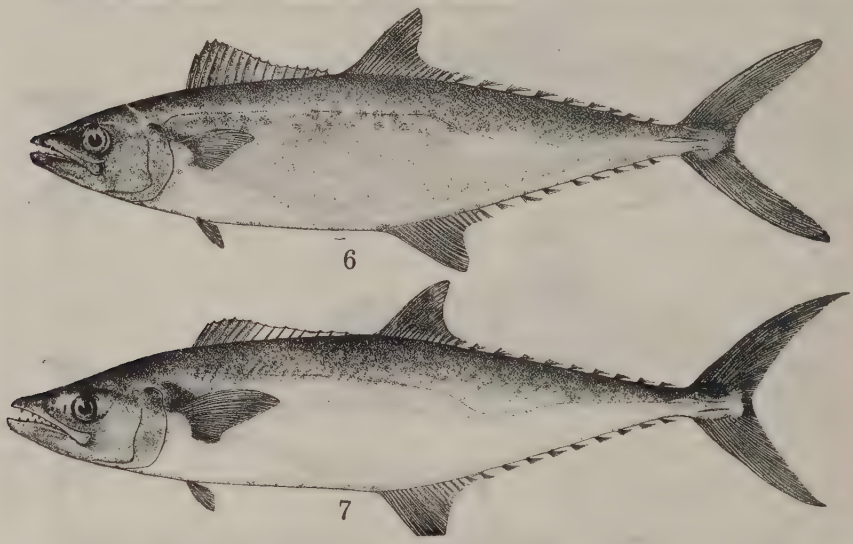
FIGS. 3-4. *Scomberomorus guttatus*. Fig. 3. 22·9 mm.; Fig. 4. 41·2 mm.

41·2 *mm. Stage* (Fig. 4).—The head is 3·3 and height 4·7 in standard length. The pre-opercular spines have become smaller and inconspicuous. The lateral line could be made out up to the vertical below the third dorsal finlet. The chromatophores have appreciably increased in number and appear as a continuous band, but not quite uniform, from the head to the caudal base. While the lateral band of chromatophores has merged with the dorsal band on each side of the body, those at the base of the anal fin and finlets have disappeared.

FIG. 5. *Scomberomorus guttatus*, 66·8 mm.

66·8 *mm. Stage* (Fig. 5).—The head is 4 and height 4·6 in standard length. The pre-opercular spines have almost disappeared completely. The

lateral line is complete. The chromatophores on the upper half of the head and body are more dense with five dense patches indicating the beginning of the characteristic colouration of the adult.



FIGS. 6–7. Fig. 6. *Scomberomorus guttatus*, 239 mm.; Fig. 7. *Scomberomorus lineolatus*, 295 mm.

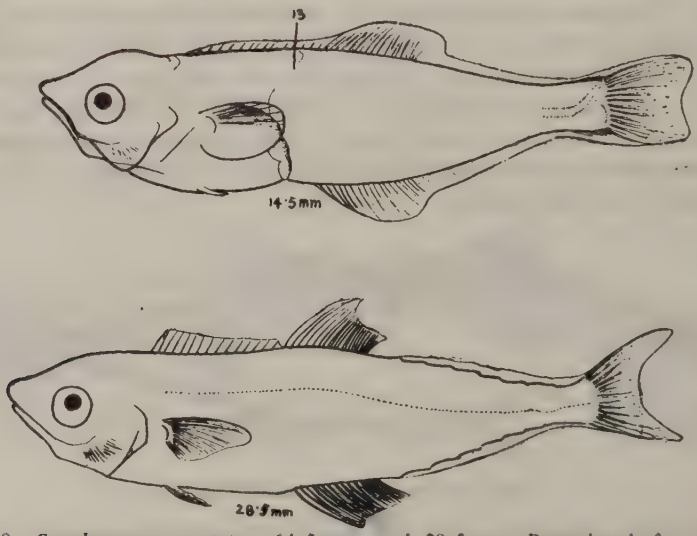


FIG. 8. *Scomberomorus guttatus*, 14·5 mm., and 28·5 mm. Reproduced from Vijayaraghavan (1955).

A juvenile specimen 239 mm. in standard length is shown in Fig. 6. It has all the unmistakable features of the adult. The head is 4·8 and height 4·4 in the body, whereas in mature adult they are about 4·1–4·5 and 3·7–4·4 respectively. The characteristic spots found on the body becomes more distinct as the fish grows in size.

With regard to the account of Vijayaraghavan (*op. cit.*) on the life-history and feeding habits of *S. guttatus*, it is quite obvious that there is some mistake in the identity of the material he had worked out. The two oldest stages figured are reproduced here for comparison (Fig. 8). To mention a few points regarding post larvae and juveniles (i) the short length of head, (ii) the obtuse-angled or blunt snout, (iii) the absence of any teeth, (iv) the absence of any preopercular spines, (v) the pre-anal length being shorter than the post-anal length, (vi) the shape of the dorsal and anal fins, (vii) the finlets not getting differentiated even in the 28·5 mm. stage and (viii) the almost total absence of chromatophores all go to show that the stages described cannot be of any *Scomberomorus* known from Indian waters. It therefore follows that the feeding habits attributed to the larvae and juveniles of *S. guttatus* do not also relate to the above species.

IX. *Scomberomorus commerson* (Lacépède)

This is the most widely distributed seerfish in the Indo-Pacific and is known from the east coast of South Africa and along the entire range of the Indian Ocean to Japan and the east coast of Australia as far as Fiji, New Caledonia and Solomon Islands. It grows to a length of over 1½ metres.

The only information we have about the development of *S. commerson* is the account by Munro *op. cit.* on the embryonic and early larval stages of the fish. He succeeded in artificially fertilizing the eggs of the fish at Watt Reef near Townsville, North Queensland and was also able to collect naturally spawned eggs from the sea. The breeding season of the fish in Queensland waters is from October to December which in the southern hemisphere corresponds more or less to the spring season. Natural spawning takes place in the early hours of the evening. A few important points from the observations of Munro (*op. cit.*) are given below as it might help the workers in the Indian region in the identification of the eggs and early larvae of this species. According to him the embryonic and larval stages resembled very much the corresponding stages of *Cybium maculatus* (= *S. maculatus*) described by Ryder (1882)*.

* It may incidentally be stated here that stages corresponding to Figs. 2-6 measuring from 2·75–5·75 mm. doubtfully referred to by Hildebrand and Cable (1938) as of *S. maculatus* do not appear to be ong to any species of *Scomberomorus*.

Clear ova from mature roes collected by him from Palm Islands had a diameter of 1·13–1·28 mm. whereas those from the Watt Reef area measured 1·23–1·38 mm. Eggs from the latter place were artificially fertilized and these had a diameter of 1·23 mm. The oil globule in all the above were of a uniform size of 0·31 mm. Naturally spawned ova collected from the same area had 1·05–1·12 mm. diameter with 0·31–0·39 mm. oil globule. The temperature of the water was 25·7° C. and salinity 36·5‰ in the sea when naturally spawned eggs were collected and the same conditions were maintained in the hatching vessels at the time of artificial fertilization.

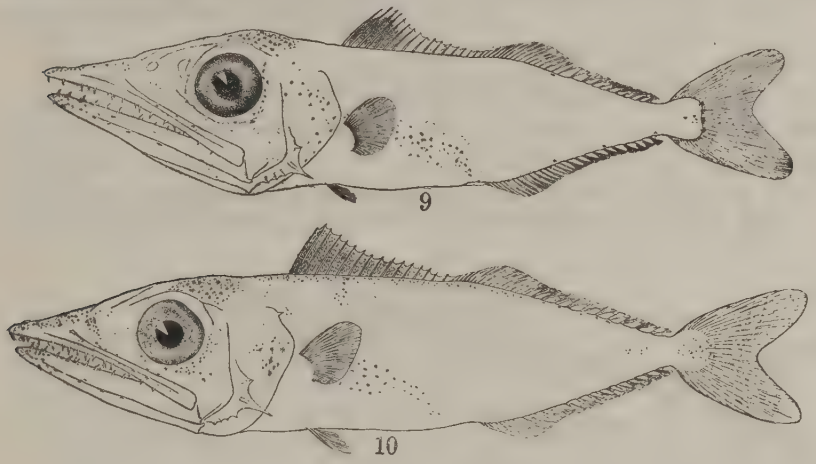
The egg floats with the oil globule at the top and the blastodisc is formed at the opposite pole where ultimately the embryo gets differentiated. The 4-celled stage is reached nearly an hour after fertilization and subsequently cell divisions take place at invervals of about 10 minutes each. At 13½ hours after fertilization the embryo has 8–9 somites and pigments begin to appear about an hour-and-a-half later. Complete investiture of the yolk by the blastoderm takes place at about 16½ hours after fertilization by which time 17 somites are discernible. At about 20 hours after fertilization the embryo shows movement and pigmentation shows a definite pattern. Hatching takes place 3–4 hours later by which time the tail portion gets appreciably elongated. The newly hatched larva is 2·5 mm. in total length with an oil globule of 0·26 mm. in diameter and floats with the yolk sac up. It grows to 3·5 mm. in another 16 or 17 hours.

The late post larvæ and juveniles described in this account were collected from shore seines from Vizhingam during the months of February to June. A large number of specimens up to about 75 mm. were available for examination. Some young specimens were examined from Madras and Waltair also. The measurements of some of these are given in Table II and some of the typical stages are described below.

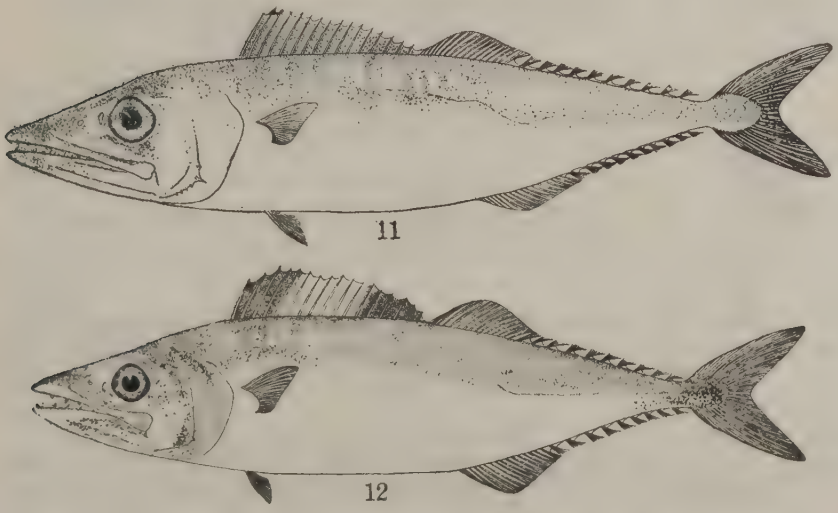
14·4 *mm. Stage* (Fig. 9).—The head is 2·3 and height 4·2 in standard length. When compared to the same stage of *S. guttatus* the snout is very long, pointed and the teeth larger and more prominent. The second spine from above on the preopercule is the longest and it projects beyond the operculum. Chromatophores are much fewer than in the corresponding stage of its congener and the dorsal and lateral bands and absent. The pigmentation in the wall of the abdominal cavity can be seen through.

24 *mm. Stage* (Fig. 10).—The head is 2·6 and height 4·5 in standard length. There is little difference from the previous stage except in the slight elongation and broadening of the body and increase in chromatophores.

A very narrow band of chromatophores is present close to the base of the spinous and soft dorsals and a chromatophore each below the first few dorsal finlets. There is a small cluster at the base of the caudal fin extending to the caudal peduncle.



FIGS. 9–10. *Scomberomorus commerson*. Fig. 9. 14·4 mm., Fig. 10. 24 mm.



FIGS. 11–12. *Scomberomorus commerson*. Fig. 11. 42·4 mm., Fig. 12. 54·5 mm.

42·4 *mm. Stage* (Fig. 11).—The head is 3·2 and height 4·7 in standard length. The preopercular spines are considerably reduced in size and appear

TABLE II

Measurements of Scomberomorus commerson *(Lacépède) in mm. (All specimens from Vizhingam)*

Sl. No.	Date of collection	Standard length	Head	Snout	Eye	Maxilla	Sn. to 1st D.	Sn. to Anal	1st dorsal spine	Depth of 1st dorsal origin	Gill rakers
1*	26-2-1959	14·4	7·01	3·35	1·62	4·86	6·81	10·04	1·36	3·87	..
2	do.	15·60	7·11	3·20	1·72	4·85	6·84	10·41	1·36	4·03	..
3	do.	16·10	7·11	3·14	1·72	4·81	7·07	11·15	1·36	4·03	..
4	do.	16·50	7·74	3·71	1·78	4·97	7·39	11·41	1·41	4·24	..
5	2-1-1959	18·80	8·04	3·61	1·88	5·23	7·80	12·92	1·46	4·45	..
6	do.	19·50	8·20	3·60	1·90	5·50	8·60	14·20	1·60	5·00	..
7	21-3-1959	20·80	8·40	3·70	1·90	5·60	8·80	14·70	1·70	5·30	..
8	2-3-1959	22·30	9·00	3·80	1·90	6·00	9·20	15·20	1·80	5·30	..
9*	do.	24·00	9·40	4·00	2·00	6·30	9·70	16·20	2·00	5·90	..
10	do.	26·50	9·80	4·30	2·10	6·60	10·10	16·80	2·00	6·10	..
11	do.	28·50	10·30	4·50	2·10	7·00	10·90	18·50	2·10	6·90	..
12	11-3-1959	37·80	13·00	5·20	2·70	8·00	12·90	24·20	2·40	8·50	..
13	do.	40·50	13·20	5·30	2·80	8·10	13·30	26·00	2·40	9·00	..
14	4-3-1959	41·70	15·80	5·70	2·90	8·60	14·00	28·20	2·70	9·30	..
15*	do.	42·40	13·90	5·80	2·90	8·60	14·20	27·90	2·80	9·20	..
16	do.	46·50	14·70	5·90	3·00	9·00	15·10	30·30	3·10	10·60	..
17*	11-3-1959	54·50	16·00	6·30	3·10	9·90	16·30	35·00	3·00	11·70	0+2
18	do.	60·20	17·50	7·00	3·30	10·70	18·70	38·00	4·00	13·00	0+3
19	1-3-1958	63·00	19·00	7·10	3·70	11·00	18·80	40·00	4·60	13·00	0+3
20	16-4-1960	91·50	25·10	9·10	4·70	14·60	26·70	57·70	6·80	19·10	0+3
21	do.	102·50	28·00	10·20	5·00	16·80	29·60	61·30	8·40	21·60	1+4
22	5-5-1959	130·50	33·00	11·90	6·10	19·30	35·20	75·60	8·70	24·60	0+3
23*	do.	137·00	35·00	12·50	6·30	20·20	37·00	80·50	8·80	26·20	1+3
24	16-5-1959	157·00	41·30	15·30	7·00	24·50	43·50	95·50	9·90	31·20	1+4
25	24-5-1959	171·00	43·90	16·00	7·10	25·20	46·70	100·00	10·30	31·50	1+4
26	do.	196·00	50·80	19·00	7·80	29·00	53·30	115·00	10·80	35·70	1+3
27	16-4-1959	213·00	53·30	19·80	7·80	30·30	57·80	122·80	11·20	38·20	1+4
28*	do.	278·00	68·50	26·00	10·00	38·50	71·00	154·00	13·20	48·50	1+4

* Denotes specimens described and figured.

only as tiny projections. The lateral line is present and is discernible up to the vertical below the 7th dorsal finlet. Only traces of the membranous interconnections between the finlets persist. Chromatophores have increased and the vertical bands are faintly indicated.

54·5 *mm. Stage* (Fig. 12).—The head is 3·5 and height 4·5 in standard length. The lateral line is complete and the opercular spines have almost completely atrophied. Membranous interconnections between the finlets persist only at their bases. The spinous dorsal has dark pigmentation anteriorly. Rudiments of the transverse bands could be seen as diffused patches along the dorsal aspect of the anterior portion of the body.

FIGS. 13–14. *Scomberomorus commerson*. Fig. 13. 137 mm., Fig. 14. 278 mm.

137 *mm. Stage* (Fig. 13).—This has all the unmistakable features of the adult. The head is 4 and height 5 in standard length. The characteristic bands on the sides of the body have begun to take shape.

A young fish 278 mm. in standard length is shown in Fig. 14. The head is 4·2 and height 5 in standard length, whereas in mature adult of over 1 metre the head is 3·7–4·4 and height 4·2–5·9 in standard length.

X. *Scomberomorus lineolatus* (Cuvier)

Scomberomorus lineolatus is the only species other than *S. guttatus* and *S. commerson* known so far from Indian waters (Jones and Silas, 1961),

It attains a length of over a metre and is often confused with the forme along with which it is caught in gill net and hook and line. There is a recent critical account of this species in East African waters by Williams (1960).

Kuthalingam (1959) refers to his collection of post larvae, juveniles and adults of *S. lineolatus* from Madras coast and has given figures of 9·5 mm. and 18·3 mm. stage which are reproduced below (Fig. 15 *a* and *b*).

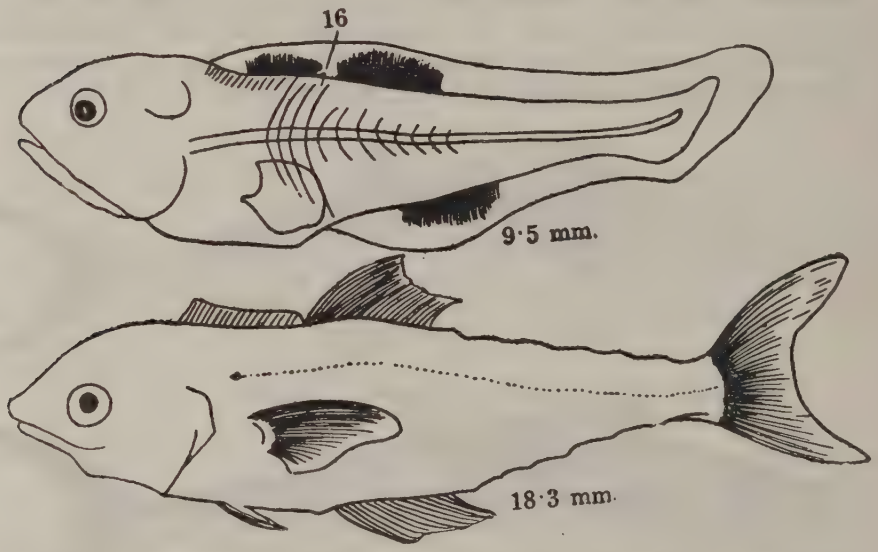


FIG. 15. *Scomberomorus lineolatus*. 9·5 mm. and 18·3 mm. Reproduced from Kuthalingam (1959).

A study of the description as well as the figures would show that they cannot be of any *Scomberomorus*. To mention a few points (i) the short and blunt snout, (ii) the general body proportions, (iii) the pre-anal length being shorter than the post-anal length, (iv) the subventral mouth with the lower jaw shorter than the upper jaw, (v) absence of teeth, (vi) absence of any spines on the pre-opercle (the pre-opercle itself is undefined), (vii) the origin of the dorsal from the occipital region of the head, (viii) the origin of the pectorals far behind the operculum, (ix) the relatively forward position of the second dorsal and anal fins, (x) the absence of finlets, (xi) the lateral line being complete even at the 18·3 mm. stage and (xii) the absence of chromatophores in the body all go to show that the larvæ and juveniles described cannot be of any *Scomberomorus*. According to him there were 31 myotomes (16 pre-anal and 15 post-anal) which itself shows that the

larvae cannot be of *S. lineolatus* which has 49 or 50 vertebræ. It may be stated in this connection that no known species of *Scomberomorus* has less than 43 vertebræ. His reference to adults measuring 100 mm. to 128 mm., a size too small for any scomberomorid to be considered an adult, is also rather puzzling.

Larval or early juvenile specimens of *S. lineolatus* have not been collected in the course of this work. The smallest specimen available in the collection is a juvenile 295 mm. in length from Tuticorin and is shown in Fig. 7 for comparison. Nothing is known about its spawning habits and development.

General Remarks

In view of the doubts that have risen about specimens described as *Scomberomorus guttatus* and *S. lineolatus* by Vijayaraghavan (*op. cit.*) and Kuthalingam (*op. cit.*) respectively, an attempt was made to re-examine the material but unfortunately this was not possible since specimens were no more available either in the Institution where the work was carried out or with the authors. This has created a rather difficult situation as any view in future about the identity of the material worked out by them could only be a matter of conjecture. It is needless to say how important it is that specimens studied and forming the basis of publications should be deposited safely for future reference. It is hoped that this aspect will receive due attention of all scientific workers and institutions in this country.

Acknowledgements

My thanks are due to Mr. K. V. Narayana Rao who collected for me most of the material described from Vizhingam and to Mr. M. Kumaran for preparing the tables and the figures of the early juveniles and for the general assistance given in the laboratory. I am indebted to Mr. D. Chakraborty for the preparation of the graph.

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STUDIES ON THE AGE DETERMINATION OF 'GHOL', *PSEUDOSCIÆNA DIACANTHUS* (LACEPEDE) BY MEANS OF SCALES AND OTOLITHS*

By K. Venkatasubba Rao

(Central Marine Fisheries Research Institute)

The fact that tropical fishes also show periodical growth checks (rings) on their discrete hard parts has been demonstrated in a few Indian species (Nair, 1949; Seshappa and Bhimachar, 1951, 1954, 1955; Pillai, 1954; Radhakrishnan, 1954, 1957; Sarojini, 1957; Jhingran, 1957; Seshappa, 1958 and Balan, 1959). Work on the biology and fishery of *Pseudosciæna diacanthus* occurring in the waters off Maharashtra and Gujarat coasts was started by the present author in March, 1958 and during the course of two years study, it has been found that the scales and otoliths of this species show growth checks (rings) which can be utilised for the determination of age and growth as was indicated by Seshappa (1953).

Scale samples from 769 fishes (5–115 cm.) and otolith samples from 350 fishes (5–100 cm.) have been studied from the landings of the trawlers of the New India Fisheries Limited and from the local 'dol' net landings. The Bull-trawlers fished mainly on the grounds off Cutch, Dwaraka, Porbunder and Veraval (Saurashtra coast) while the local 'dol' nets were operated off Bombay in 20–40 metres depths. Scales from the region immediately posterior to the tip of the pectoral fin were always selected.

The growth checks (rings) of the scales are of the nature of breaks or interruptions of the pattern of the circuli, more clear at the antero-lateral corners of the scale. Closer approximation of a few circuli, apparently not forming bands, has also been observed in the scales of younger fish. Another characteristic feature is the increase in the number of radii outward of the ring, the new radii commencing just near the ring and the portion of the radii inside and outside the ring being often not in a line. In the scales of older specimens with five or more rings, the rings (1 or more) near the periphery were observed to be more clear and conspicuous than the inner 3 or 4 rings. The frequency distribution of these rings observed on the scales of 769 fishes is given in Table I.

TABLE I

Table showing the frequency distribution of rings in the scales of Ghol, Pseudosciæna diacanthus (*Lacépède*)

Size group in cm.*	Number of fish examined	Number of rings in the scales								
		0	I	II	III	IV	V	VI	VII	VIII
5– 9	1	1								
10– 14	20	20								
15– 19	62	62								
20– 24	55	55								
25– 29	27	23	4							
30– 34	26	21	5							
35– 39	25	6	19							
40– 44	23	..	23							
45– 49	20	..	20							
50– 54	23	..	22	1						
55– 59	14	..	7	7						
60– 64	16	..	2	14						
65– 69	21	..	..	21						
70– 74	28	..	..	26	2					
75– 79	29	..	..	7	22					
80– 84	39	..	..	1	29	9				
85– 89	68	..	..	..	7	61				
90– 94	89	..	..	..	..	67	22			
95– 99	88	..	..	..	..	10	78			
100–104	66	..	..	..	..	..	43	22	1	
105–109	23	..	..	..	..	..	3	11	9	
110–114	6	..	..	..	..	..	..	3	2	1
Total ..	769	188	102	77	60	147	146	36	12	1
Average length of fish with rings		..	44·6	68·3	80·9	89·97	99·5	104·3	107·6	113·5

* Total length in cm. from the tip of the snout to tip of the longest ray of caudal fin.

The highest number of rings observed in the scales so far is 8 from a specimen measuring 113·5 cm. in length. The average length of fish having different number of rings is also given in Table I.

Time of formation of the rings.—Scales with 'Open' margins were observed during all the months and those with exactly closed margins have been rarely found. The time of formation of these checks was found out by the method employed by Perlmutter and Clarke (1949). There was not much difference in the width of the space between circuli within a zone enclosed by a ring. The width of the space between circuli differed in various zones, the circuli being much closer to each other in the inner zones and the width between them increasing in the outer zones. So also, the width (*i.e.*, number of circuli) of the zones enclosed by the different rings varied. The inner two zones enclosed by the first and second ring were wider than those

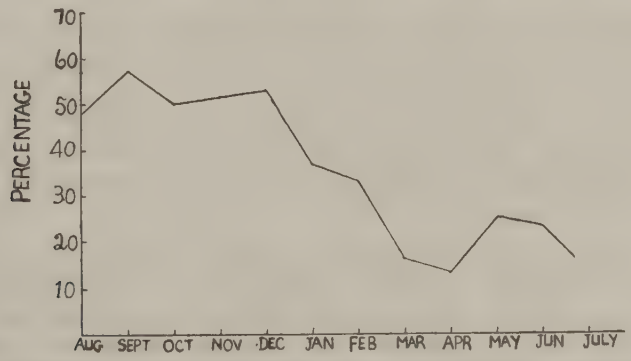

Fig. 1. Percentage of scales with minimum circuli count (width) in the terminal zone in different months.

towards the periphery which were narrower. Keeping in view this difference in the width of the zones between different rings, different circuli counts have been considered for finding the percentage of scales with minimum width (circuli count) of the terminal zone (zone between the last ring and the scale edge). For scales with 1–3 rings those with less than 25 circuli in the terminal zone have been taken as having minimum width. Similarly in the case of scales with 4 rings and 5 or more rings those with less than 10 and 5 circuli respectively in the terminal zone have been considered as having minimum width. The percentage of scales with minimum width and circuli count in terminal zone were observed to be high during the period August to January (Text-Fig. 1) which period appears to be the time of formation of rings.

There seems to be good agreement between the size of the age groups observed in the length frequency distributions and the average size of the fish having 1–5 rings on their scales. The modes at 42·5–47·5 cm., 67·5–72·5 cm., 77·5–82·5 cm., 87·5–92·5 cm. and 97·5–102·5 cm. observed in the length frequency distributions of samples from the trawlers can be taken as representing the age groups I, II, III, IV and V respectively. The first ring seems to be formed after completion of one year. The spawning season for this species is protracted extending from June to September.

The growth checks in the otoliths are of the nature of translucent (hyaline) rings. Though the material studied is limited, the results are encouraging and are in close agreement with those observed in scales. The distribution of the translucent rings in different size groups is more or less similar to those of scales. The otoliths examined were from the same specimens used for scale studies.

Otoliths from specimens 30–60 cm. in length show 1, 65–75 cm. 2, 75–85 cm. 3, 85–95 cm. 4, and 95–100 cm. 5 rings respectively.

In the otoliths examined from specimens 38–46 cm. in October-November, the first translucent ring had been formed and the edges were still translucent. It is most likely that the translucent ring is formed during this period or just before as is the case in scales.

Low feeding may be responsible for the formation of these rings, particularly among the juveniles. A study of the food and feeding habits of the juveniles (below 25 cm.) in the inshore waters around Bombay has shown that the feeding intensity of the juveniles of this size is high during September–December and declines gradually thereafter reaching the minimum by March–April. The scales of this size group do not show first growth ring and the otoliths show only the inner opaque zone. Thus there is circumstantial evidence to show that the formation of opaque zone in the otolith is connected with high feeding intensity. 40–50 cm. specimens showing one growth ring in their scales and otoliths are not found in the inshore catches during September–January and it is probable that they live in deeper waters. Among the adults it is possible that the strain of spawning activity would also induce the formation of the rings and that is probably the reason why the fifth and subsequent rings appear clearer and more conspicuous than the earlier ones.

The sudden change in the hydrological conditions of the waters in the region between Latitude 20° N. and 22° N. due to the commencement of N.-E. monsoon characterised by abrupt change from high surface temperature

and low salinity of October-November period to low temperature and high salinity from November end to February observed by Jayaraman and Gogate (1957) and the low bottom temperature especially in the Dwaraka region (22° N.) from December–February (Jayaraman *et al.*, 1959) may also have a bearing on the formation of growth rings.

Acknowledgements

I am grateful to Dr. S. Jones, Director, for kindly suggesting this problem and for his guidance and encouragement in this work. My thanks are due to Dr. G. Seshappa and Shri K. H. Mohamed for kindly going through the manuscript of this paper and for offering valuable criticism and suggestions for its improvement.

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Plate I

Photograph 1. A scale of 'Ghol' showing one growth ring, ×5. Total length of fish: 48·0 cm. Date of collection: 25-1-1960.

Photograph 2. A scale of 'Ghol' showing two growth rings, ×4·2. Total length of fish: 72·5 cm. Date of collection: 6-3-1959.

Photograph 3. A scale of 'Ghol' showing three growth rings, ×3·3. Total length of fish: 77·5 cm. Date of collection: 13-3-1959.

Photograph 4. A scale of 'Ghol' showing five growth rings, ×3. Total length of fish: 96·8 cm. Date of collection: 6-3-1959.

Photograph 5. A scale of 'Ghol' showing six growth rings, ×2·3. Total length of fish: 106·0 cm. Date of collection: 19-3-1960.

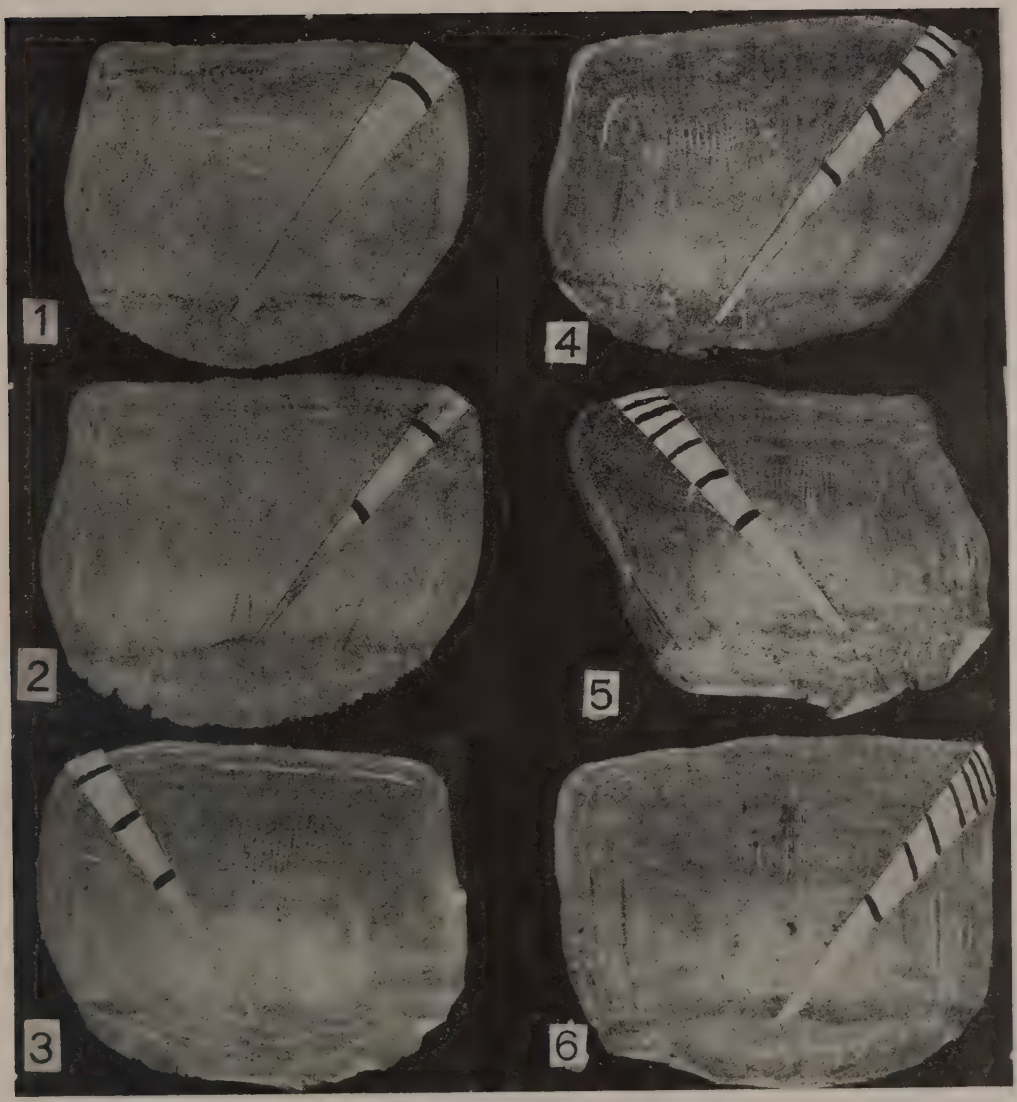
Photograph 6. A scale of 'Ghol' showing seven growth rings, ×2. Total length of fish: 108·0 cm. Date of collection: 5-3-1959.

Plate II

Photograph 1. Otolith of 'Ghol' showing one translucent growth ring near the margin, ×3. Total length of fish: 42·1 cm. Date of collection: 18-11-1958.

Photograph 2. Otolith of 'Ghol' showing two translucent growth rings, ×3·8. Total length of fish: 64·5 cm. Date of collection: 27-2-1959.

Photograph 3. Otolith of 'Ghol' showing four growth rings and opaque zone, ×2·5. Total length of fish: 96-0 cm. Date of collection: 28-12-1960



PHOTOGRAPHS 1-6

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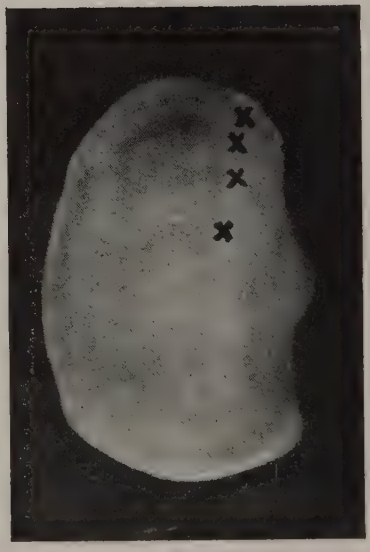

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PHOTOGRAPHS 1–3

BIOLOGY AND FISHERY OF 'CHOO PARAI'— *SELAROIDES LEPTOLEPIS* (CUVIER AND VALENCIENNES)

Part II. Biology and Fishery

By K. K. Tandon

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I. Introduction

The present account, dealing with the biology and fishery, forms the second part in the series on the study of *Selaroides leptolepis*. Details regarding the material which formed the basis of this work have already been given in the earlier paper (Tandon, 1960).

II. Distribution

The genus *Selaroides* is represented by a single species, *leptolepis* and is fairly common from the Persian Gulf to the Riu Kiu islands in Japan. In India it has been recorded from Vizhingam near Trivandrum (West Coast), Tuticorin, Kailakarai, Periapatnam, Pudumadam, Vedalai, Mandapam, Rameswaram Island, Theedai, Panaikulum, Devipatnam, Madras and the areas adjoining it and Visakhapatnam (East Coast).

III. Length-Weight Relationship

For the study of the length-weight relationship of *S. leptolepis*, the equation of the form of general parabola $W = aL^n$ was used, where W represents weight of fish in gm., L, the fork length in centimetres and a, a constant and n, an exponent to which L can be raised. Le Cren (1951) pointed out that this formula has got superiority over the cubic formula $W = aL^3$, since the former besides providing a means for calculating weight from length, and a direct way of converting logarithmic growth-rates calculated on lengths into growth rates for weights, may also give an indication of taxonomic differences and events in the life-history, such as metamorphosis and the onset of maturity while the latter can be used only if the form and specific gravity are constant throughout life. The value of the exponent n usually lies between 2·5 and 4 (Hile, 1936; Martin, 1949) and for an individual fish which maintains the same shape $n = 3$ (Allen, 1938).

The fresh fish were first measured and then the excessive moisture was removed by pressing in between two blotting papers.

Samples of fish collected during different months of 1957 and 1958 were studied from all the centres of observations. The observed values of lengths and weights were transformed into logarithmic values and the equations were calculated by the method of least squares.

Males and females in each month were treated separately and those collected from Pudumadam during May 1957 were analysed by the method of Analysis of Covariance. The relevant details are given in Tables I to III.

TABLE I

Statistics of the length-weight relationship of males and females of Selaroides leptolepis

Sex	N	SX	SY	SX^2	SY^2	SXY
Male ..	18	17·4548	18·8488	16·9653	20·3594	18·4296
Female ..	32	30·4641	31·9308	29·0374	32·3736	30·5231

N = Number of fish.

SX^2, SY^2, SXY = Sum of squares and products.

SX, SY = Sum of logarithmic values of fork lengths and weights respectively.

TABLE II

Regression data of length-weight relationship of males and females of Selaroides leptolepis

Sex	D.F.	Sum of squares and products			b	Errors of Estimate	
		x^2	xy	y^2		D.F.	S.S.
Male ..	17	0·0392	0·1517	0·6218	3·87	16	0·0347
Female ..	31	0·0355	0·1249	0·5119	3·52	30	0·0725

D.F. = Degrees of freedom.

b = Regression coefficient.

TABLE III

Test of significance

Source of variation	Degrees of freedom	Sum of squares	Mean square	Observed F	5% F
Deviation from individual regressions within sexes	46	0·1072	0·00233	1·0130	252
Differences between regressions	1	0·0023	0·0023		
Deviation from total regression	47	0·1095			

It may be seen from Table III that males and females do not differ significantly. The data were then pooled and a common value of *n* was found out. Table IV gives the value of *n* for the pooled data from May 1957 to October 1957 and April 1958 for Thangachimadam, and May 1957 to March 1958 for Pudumadam.

TABLE IV

'n' *Values from Thangachimadam and Pudumadam*

Months	Thangachimadam	Pudumadam
May 1957 ..	3·73	3·66
June ..	3·46	..
July ..	3·04	..
August ..	3·31	3·55
September ..	2·99	..
October ..	3·10	2·88
November ..	..	3·40
December ..	..	3·43
January 1958 ..	..	..
February ..	..	3·02
March ..	..	2·18
April ..	3·36	..

Hickling (1940) in his studies on herrings observed that in an advanced state of maturity the weight of the entire fish increases with length, at a rate much less than the cube of the length, and therefore the fish alone, without the gonads and gut, must increase, with length at an even slower rate, nearer the square than the cube of the length. In the light of these observations it may be said that the least values of '*n*' can be made use of to find out the spawning season or more precisely the advanced state of maturity of the fish, which as shown in Table IV will be September–October and February–March.

Separate equations for immature, maturing, mature, spent* and gutted individuals were also calculated as described above and they were found to be as follows:

Immature .. $W = 0{\cdot}006540\ L^{3{\cdot}3853}$

Maturing .. $W = 0{\cdot}08984\ L^{3{\cdot}2066}$

Mature .. $W = 0{\cdot}07137\ L^{3{\cdot}2943}$

Spent .. $W = 0{\cdot}05657\ L^{2{\cdot}4237}$

Gutted .. $W = 0{\cdot}009317\ L^{3{\cdot}1730}$

The length-weight values for different stages of maturity and gutted fish were then analysed by the method of Analysis of Covariance. Results are given in Tables V to VII.

TABLE V

Statistics of the length-weight relationship of immature, maturing, mature, spent and gutted fish of Selaroides leptolepis†

Character	N	SX	SY	SX^2	SY^2	SXY
Immature ..	70	59·4808	48·4476	50·7285	35·8894	41·7972
Maturing ..	50	51·2186	61·9152	52·5482	77·6207	63·6849
Mature ..	50	53·9731	70·4863	58·3217	100·1330	76·2843
Spent ..	50	51·9369	63·5071	53·9606	80·7577	65·9958
Gutted ..	70	73·0794	89·7304	76·4226	116·3636	94·0849

† Notations are same as in Table I.

* For definition of maturity stages refer to Section IV.

TABLE VI

Regression data of length-weight relationship of immature, maturing, mature, spent and gutted fish of Selaroides leptolepis*

Character	D.F.	Sum of squares and products			*b*	Errors of Estimate	
		x^2	xy	y^2		D.F.	S.S.
Immature	69	0·1861	0·6300	2·3584	3·3853	68	0·2257
Maturing	49	0·0813	0·2607	0·9509	3·2066	48	0·1149
Mature ..	49	0·0598	0·1970	0·7666	3·2943	48	0·1176
Spent ..	49	0·0118	0·0286	0·0947	2·4237	48	0·0254
Gutted ..	69	0·1283	0·4071	1·3415	3·1730	68	0·0498

* Notations are same as in Table II.

TABLE VII

Test of significance

Source of variation	Degrees of freedom	Sum of squares	Mean squares	Observed F	5% F
Deviation from individual regressions within different stages of maturity and gutted fish	280	0·5334	0·0019	1·6316	2·39
Differences among regressions	4	0·0124	0·0031		
Deviation from total regression	284	0·5458			

It may thus be seen from Table VII that the length-weight relationship for different stages of maturity and gutted fish does not differ significantly. Hence a pooled equation for the entire data was calculated which gave the following value:

$$W = 0{\cdot}01089\ L^{3{\cdot}1182}$$

The logarithmic equation was found out to be

$$\log W = -1{\cdot}9628 + 3{\cdot}1182 \log L.$$

The observed values for the corresponding lengths and weights are plotted in Fig. 1 and show a close fit to the calculated values. The logarithmic values for lengths and weights are plotted in Fig. 2 which gives a straight line relationship.

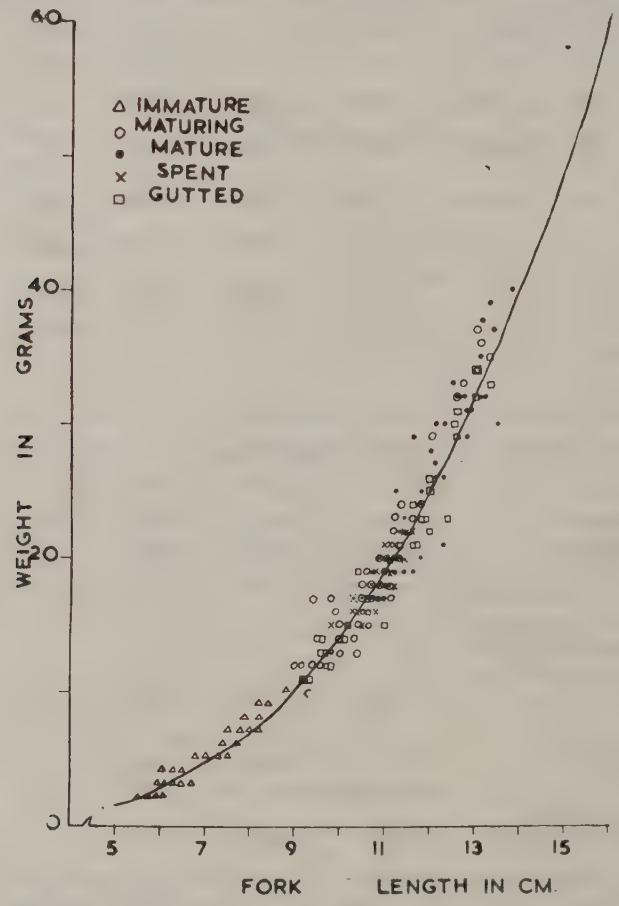

FIG. 1. Length-weight parabola of *Selaroides leptolepis*.

IV. CLASSIFICATION OF MATURITY STAGES

The maturity stages given by the International Council for the Exploration of the Sea could not be adopted for the species under discussion and

therefore a different classification has been found necessary. The stages followed in this investigation corresponding with those described by I.C.E.S. (for comparison) are given below:

Stages followed	Stages described by I.C.E.S.
I. Ovaries small, pin head-like structures, flesh-coloured. Eggs not visible to the naked eye	I
II. Ovaries occupy $\frac{1}{2}$ the body cavity, translucent, flesh-coloured, ova are visible to the naked eye, traces of yolk appear (includes spent-recovering also)	II
III. Ovaries occupy $\frac{3}{4}$ of the body cavity, opaque, with large partially yolk laden ova. The ovaries have a tinge of yellow colour	III and IV
IV. Ovaries fully occupy the body cavity, eggs large, fully laden with yolk, golden yellow in colour, a few ova may be semi-transparent	V
V. Ovaries swollen, yolk almost transparent and eggs reach their maximum diameter, single oil globule present (spawners)	VI
VI. Spent. Ovaries bloodshot, a few degenerating ova can be seen (spent-recovering ovaries look like stage II described above)	VII

For the sake of convenience Stage I will be described, hereafter, as immature, Stages II and III as maturing, Stage IV as mature and Stage VI as spent. Stage V indicates spawners.

V. Seasonal Progression of Ova

Fresh ovaries were preserved in 5 per cent. formalin and when sufficiently hardened, small portions were teased on the slide and the ova spread as evenly as possible. The diameters of the eggs were measured with an ocular micrometer at a magnification which gave a value of 19 μ to each micrometer division. It should be pointed out here that an ovum which measured more than 114 but less than 133 μ was treated in a higher group and so on.

The measurements of ova from each fish were grouped into size intervals of 38 μ. The different regions of the ovary do not show any significant difference either in the relative number or in the pattern of their production. Thus in the subsequent studies ova were measured from the middle portion and only those measuring 95 microns and above were taken into consideration.

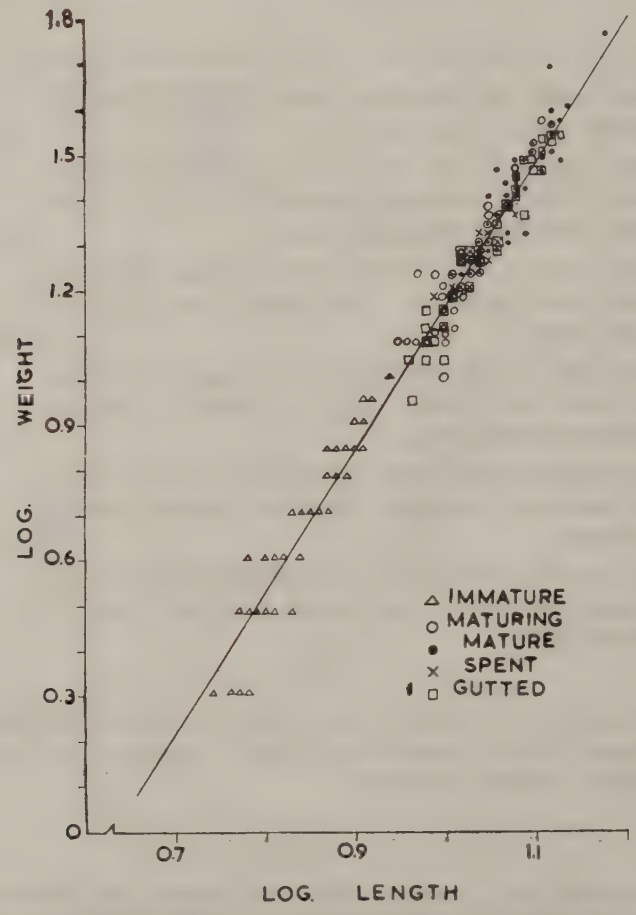

FIG. 2. Logarithmic relation of length and weight in *Selaroides leptolepis*.

The maximum diameter of ova in Stage I is 114 μ; 190 μ in Stage II; 304 μ in Stage III; 494 μ in Stage IV; and 646 μ in Stage V. Each ovum of Stage V is perfectly spherical with its almost transparent yolk and a

slightly eccentrically placed pink oil globule, the diameter of which varied from 152 to 171 μ.

For the seasonal progression of ova, fish were examined every month and the percentage frequencies of ova are plotted in Fig. 3. The samples of

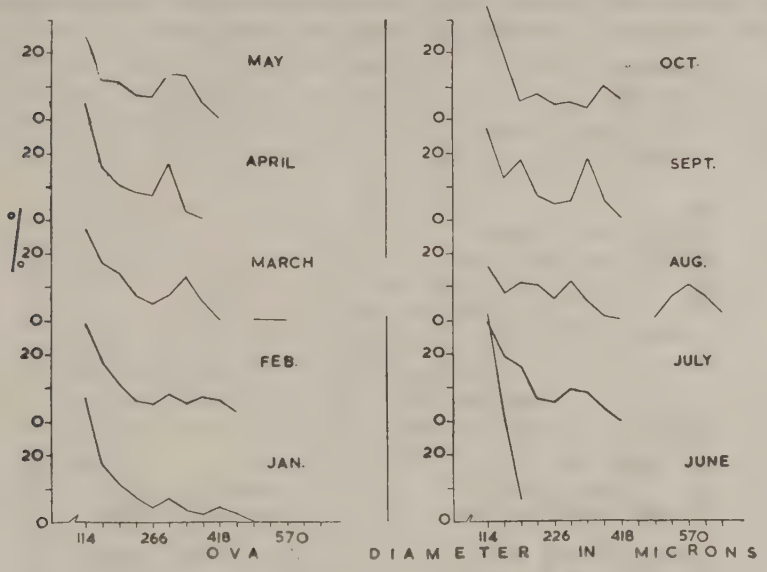

FIG. 3. Seasonal progression of ova in *Selaroides leptolepis*.

January show the presence of three groups of ova. The first group which consists of ova up to size of 114 μ are found as a dominant group throughout the year. This is the immature group of ova which would give rise to the eggs that would be spawned during the succeeding season. The second group with a mode at 304 μ is the maturing and the third with a maximum diameter of 494 μ is the mature group. From January onwards there is an increase in the relative number of ova although the maximum diameter remains more or less the same in February.

In March there is a noticeable increase in size of ova and those of Stage V have separated from the rest of the stock. Before this group of ova is completely shed, another makes its appearance which will be spawned subsequently. This is clear from the polygons for the months of April and May. This shows that first spawning takes place in the months of February and March. In June all the fish examined had mostly immature ova but the

polygons for July show an increase in the size of ova. In August maximum size of the ova is attained. This group of ova has a mode at 570 μ and is separated from the rest of the stock. Before this group is shed, another group has already made its appearance and this will be spawned in the next spawning season. The graphs for the months of March and August, therefore, indicate that there are two spawning seasons and these are confirmed by the occurrence of juveniles and Stage IV twice a year.

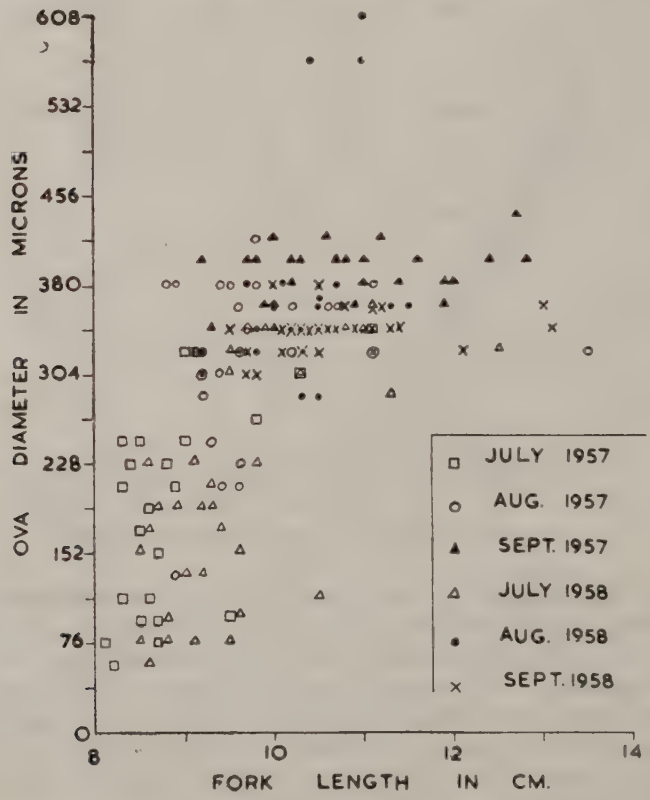

FIG. 4

VI. SIZE AT FIRST MATURITY

The size at first maturity in females was found out from the ova diameter studies during the spawning seasons. For this purpose, the biggest diameter of common eggs was taken into consideration. The females between 8·0 and 14·0 cm. were examined. Spent ovaries were excluded. The results are plotted in Figs. 4 and 5. In Fig. 4 three groups of ova can be made out—the

first group between 38 and 114 μ, second between 115 and 304 and third above 304 μ. Most of the fish in July have ova falling in first and second groups, but a few ova of third group are also present. In August most of the fish fall in the third group and in September, with the exception of a few fish, all have ova more than 304 μ showing thereby that it is the period of intensive spawning. Observations for January, February and March 1958 and 1959 are plotted in Fig. 5, where more or less similar results as in Fig. 4 can be made out. Here the period of intensive spawning is February. From Fig. 4, it is inferred that a few fish mature between 8·8 and 9·0 cm., slightly more in 9·1–9·5 cm. and more than 50 per cent. are mature from 10·1 cm. and above. Thus the size at first maturity may be said to be 8·8 cm.

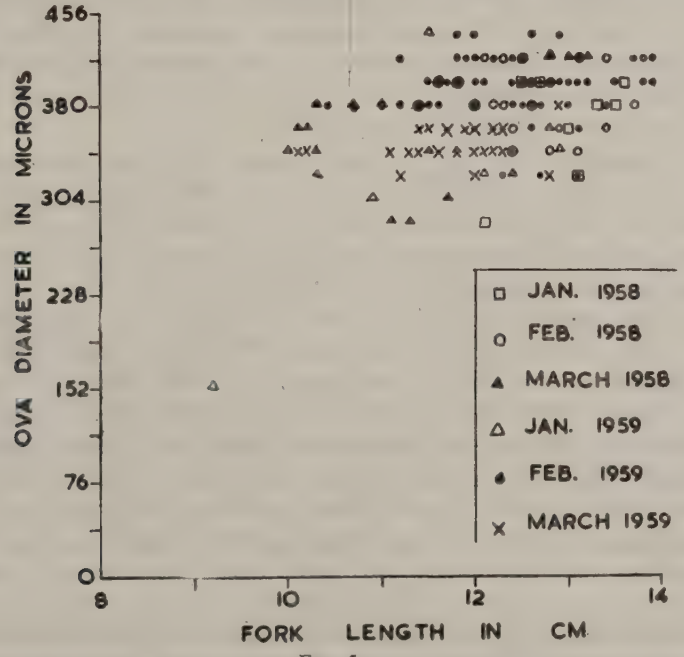

FIG. 5

FIGS. 4 and 5. Size at first maturity in females as determined by the ova-diameter studies during the spawning seasons in *Selaroides leptolepis*.

Prabhu (1956) stated that females of *Caranx* (*Selaroides*) *leptolepis* attain a size of 13·9 cm. at first maturity. It is, however, not clear whether it is the total length or fork length. The total length of a specimen measuring 8·8 cm. (the size at first maturity in the present investigation) is not more than 10·2 cm. and thus the size at first maturity recorded by Prabhu (*op. cit.*) is much higher. It may be stated that he examined specimens in

the month of February from Rameswaram Road. At this centre, individuals smaller than 10·5 cm. (total length) occur very seldom. It is, therefore, not surprising that he did not come across smaller individuals with ripe gonads.

VII. Spawning

The spawning season was determined on the basis of occurrence of fish of different maturity Stages at Thangachimadam, Rameswaram, Rameswaram Road and Pudumadam during May 1957 to May 1959. It was found that Stage IV occurred from May to October 1957 with a maximum of 53 per cent. in September at Thangachimadam. In 1958 all the females examined were mature in March and 58·21 per cent. in April. In September, both mature and spent individuals with a total percentage of 58·06 were noticed. In 1959 higher percentage of mature individuals was recorded again in March and April and so do the spent individuals. The occurrence of the juveniles in April/May and sometimes in June is a further proof of the fish having spawned sometimes during February/March.

At Pudumadam, mature specimens started occurring from January 1958 with the peak in February. In March the total percentage of mature and spent individuals was 64·60 per cent. In April 96·55 per cent. of the individuals were in spent condition and in May 100 per cent. The mature individuals appeared again in July but their percentage was low. In August 26·53 per cent. were mature and 6·12 were in the ripe stage. In September all were in the mature state. By the end of 1958 mature individuals again started appearing. In February and March 1959 individuals of Stage IV were maximum. Hence the fish spawn twice, once during January to March/April with the peak in February and second time during July/August to October with the peak in September. This is in agreement with the earlier observations of De Jong (1940) and Prabhu (1956).

The biannual spawning of the fish is further confirmed by the changes in temperature and plankton in the waters around Mandapam. That the temperature is one of the controlling factors in the process of spawning in temperate and cold water species has been shown by earlier workers (Orton, 1920; Qasim, 1956). The richness of the local waters in plankton in the months of February to March/April and August to October (Prasad, 1957, 1958) indicates that the biannual spawning has developed in correlation with the available plankton food and change in temperature.

VIII. Relation between the Weight of the Fish and the Ovaries

Ovaries were weighed from the specimens collected from Thangachimadam during March to October 1958 to find out their probable effect

on the spawning season of the fish. The data for January, February, November and December were not available for analysis due to the absence of fishing at this centre.

The formula $W_0 = A W^b$ was employed to find out the relationship between the weight of the ovaries and weight of fish where W_0 and W denote weights of ovaries and fish in mg. and gm. respectively, and A and *b* are two constants. The values of *b* for the different months are given in Table VIII.

TABLE VIII

'b' *Values from different months at Thangachimadam during* 1958

Months	*'b'*
March ..	1·0075
April ..	1·9616
May ..	2·3638
June ..	2·4168
July ..	2·4781
August ..	2·2194
September ..	1·9066
October ..	0·8809

The low values in March and October indicate the condition of the ovaries and this can be expected only when the fish are in the spent condition. Thus it may be inferred that the fish had spawned once prior to March and second time prior to October, confirming thereby the biannual spawning.

IX. FECUNDITY

Fecundity in *S. leptolepis* was calculated from the mature females from Thangachimadam during September–October, and from Pudumadam during February–March. The ovaries were removed carefully and preserved in 5 per cent. formalin until they were sufficiently hard. The excessive moisture was removed and the ovaries were weighed on a chemical balance. The weights were taken up to the nearest milligram. From the known weight of the ovaries a portion was cut and weighed. The ova visible to the naked eye in this piece were counted by separating them with the help of fine needles. From the number of the ova in the piece total number of the ova were computed.

The fecundity was studied in relation to length of fish and weight of ovaries. The general parabolic equation of the form $F = A L^x$ was used for length and $F = A W_0^x$ for weight of the ovaries, where F is the number of eggs in thousands, A is a constant and x an exponent showing the relation between F and L and F and W_0; L is in mm. and W_0 in mg.

The equations for Pudumadam were

$$F = 0{\cdot}004496\ L^{3.1618}$$

$$F = 4{\cdot}555\ W_0^{1.2476}$$

and for Thangachimadam

$$F = 0{\cdot}02569\ L^{2.8265}$$

$$F = 67{\cdot}63\ W_0^{1.0313}$$

Figures 6 and 7 show the scatter diagrams from Pudumadam for number of ova against length of fish and weight of ovaries respectively. Similarly Figs. 8 and 9 give the same relations from Thangachimadam. It may be seen from these figures that the observed values lie fairly close to the calculated values. It would thus be concluded that fecundity increases at a rate of 2·8265 in relation to length from the bag-net samples of Thangachimadam and at a somewhat higher rate from the shore-seine samples of Pudumadam, which may be attributed to the gear selection and the time of the determination of fecundity. The fecundity data from Thangachimadam correspond to September–October 1957, whereas from Pudumadam the data were collected during February–March 1959. The fecundity ranges from 6,304 ova at 9·5 cm. to 37,375 ova at 13·1 cm.

X. Sex-Ratio

The studies on sex-ratio are essential so as to know whether a differential fishing exists or not.

Sex-ratio of *Selaroides leptolepis* was studied from the weekly samples collected from Thangachimadam, Pudumadam, Rameswaram and Rameswaram Road. The figures were then calculated for the whole month from each place. The studies indicated the occurrence of more females than males in all the months. However it was found that during the spawning season the differences between the two sexes were much less. The data for the entire period when analysed showed a ratio of 1 male : 1·25 females at Thangachimadam, 1 male : 1·57 females at Pudumadam ; 1 male: 2·81 females at Rameswaram ; and 1·17 males: 1 female at Rameswaram Road.

The pooled data for the entire period from the four places indicated that during spawning months, the two sexes were almost in equal numbers. The variation in their ratio occurred before and after these months. Thus there appears to be no differential fishing at least during the spawning season.

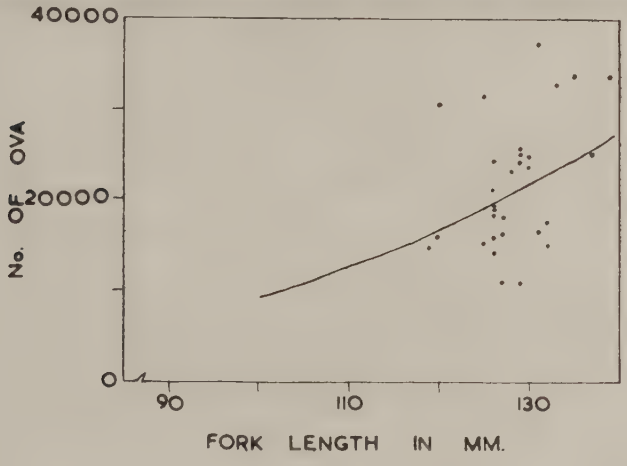

FIG. 6

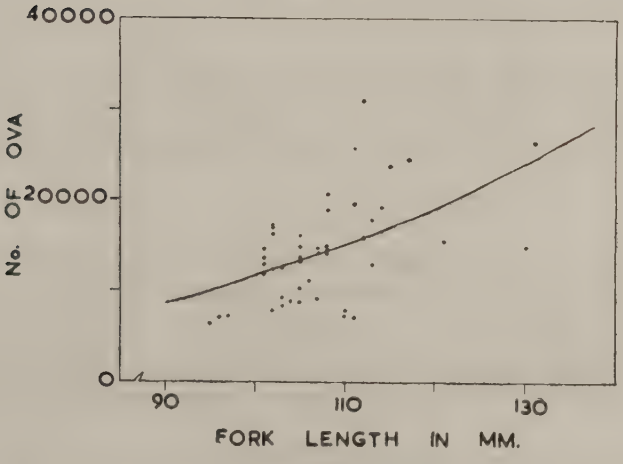

FIG. 8

FIGS. 6 and 8. Relation between the fork length and the number of ova produced from the Pudumadam and the Thangachimadam samples respectively in *Selaroides leptolepis*.

Before and after that period more females were caught. During the course of three years' investigation 4,330 specimens were studied, out of which 1,645 were males, 2,372 females and 313 indeterminates.

It may thus be inferred that males and females appear to congregate in almost equal number during the spawning season and after it is over, they segregate. This may explain nearly 1 : 1 ratio during the spawning season. However the reasons for the slight changes in the sex-ratio during the spawning seasons noticed at different centres are not known at present.

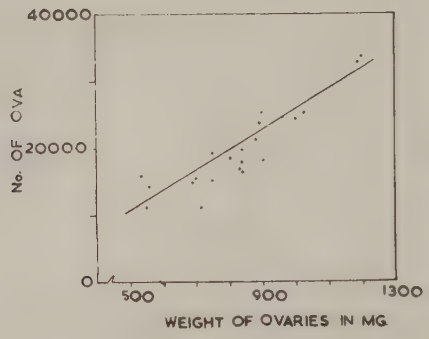

FIG. 7

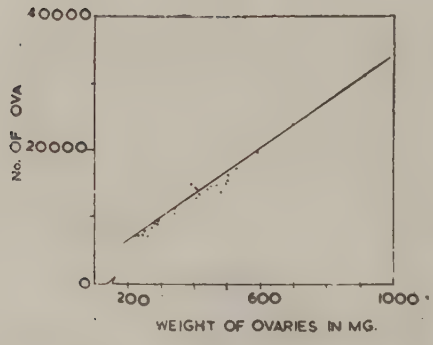

FIG. 9

FIGS. 7 and 9. Relation between the weight of ovaries and the number of ova produced from the Pudumadam and the Thangachimadam samples respectively in *Selaroides leptolepis*.

XI. FISHERY

Selaroides leptolepis continues to occur throughout the year and forms a good fishery in the months of February to May and August to October, the peak period being February and September—when ripe, spent, and spent recovering individuals are met with. In April–May and October–November juveniles are common.

The fishery is constituted by the size groups ranging from 8–13 cm. and includes maturing, mature, spent and spent-recovering individuals. During April–May shoals of 5–8 cm. are also of common occurrence. From the data collected it has been noticed that the maximum size of the fish caught by the nets, operated in this locality, is 15·3 cm. However such large individuals rarely occur in the commercial catches.

XII. Summary

1. The distribution of *Selaroides leptolepis* has been described.

2. Length-weight relationship of the fish is governed by the formula:

$W = 0{\cdot}01089\ L^{3{\cdot}1182}$.

3. The study of the seasonal progression of ova indicated the biannual spawning of the fish—once during February to March/April and second time during July/August to October, the peak periods being February and September. The biannual spawning was also confirmed by the relation between the weight of the fish and ovaries during different months.

4. Females attain a size of 8·8 cm. at the time of first maturity.

5. Fecundity varies from 6,304 ova at 9·5 cm. to 37,375 ova at 13·1 cm.

6. The two sexes are almost in equal number during the spawning seasons, variations in their number occur before and after the spawning.

7. Fishery is constituted by the size groups ranging from 8–13 cm.

XIII. Acknowledgements

In the preparation of this paper, my heartiest thanks are due to Dr. S. Jones, Chief Research Officer, and Dr. R. Raghu Prasad, Senior Research Officer, Central Marine Fisheries Research Station, Mandapam Camp, for their kind help, suggestions, criticism and for going through the manuscript.

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SCALES AND OTOLITHS OF THE 'KOTH' *OTOLITHOIDES BRUNNEUS* (DAY) AS AGE INDICATORS*

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Growth rings on the scales and otoliths of 'Koth' have been recorded by Karandikar and Thakur (1951). Mention of growth checks on the scales of this fish and their probable utility in age determination has also been made by Seshappa (unpublished). Studies on the scales and otoliths of 'Koth' from the local 'dol' net catches landed at Bombay and the catches of the trawlers working along the Bombay coast were begun by the author in February 1958 with a view to assess their value in age determination of the fish. Material for the present study was also collected subsequently from the gill-net catches at Bedi in the Gulf of Cutch.

Five to six scales each from the pectoral region of 554 fish, ranging in size from 5·0 to 150·5 cm., were examined. Scales of 'Koth' are found to lack zonations of wide and narrow sclerites, the concentric markings of the rings being abrupt breaks in the pattern of the circuli. This feature in the scales has been reported in *Lates calcarifer* also by Australian workers (Ommaney, 1957). Generally, 'Koth' above 30 cm. in length (total length) had one or more clear rings on their scales. A maximum of twelve rings were counted on the scales of a fish of 149·0 cm. in length. The progressive increase in the number of scale rings with fish size was evident from the observed mean fish size for each ring, from the first to the twelfth (*vide* Table I).

The mean fish sizes for the first three scale rings, *i.e.*, 41·8, 60·0 and 74·1 cm. respectively, more or less correspond to the first three modes in the length frequency curves of 'Koth' from the catches landed at Bombay. The modes of the curve for the 1958–59 catches were at 38·5, 59·5 and 80·5 cm., for the 1959–60 catches at 24·5, 59·5 and 87·5 cm. and for the 1960–61 catches at 31·5, 59·5 and 73·5/80·5 cm.

In order to check the annual nature of the formation of the scale rings, counts of circuli in the 'terminal zone' of the scale (Pl. III, Fig. 1) from 305

TABLE I

Distribution of scale rings of 'Koth', Otolithoides brunneus *at various size groups**

Size group in cm.	Number of rings												
	0	1	2	3	4	5	6	7	8	9	10	11	12
5·0– 27·9 ..	44	..	..	..	..	..	..	..	..	..	..	..	..
28·0– 34·9 ..	40	24 (2)	..	..	..	..	..	..	..	..	..	..	..
35·0– 41·9 ..	35	55 (4)	..	..	..	..	..	..	..	..	..	..	..
42·0– 48·9 ..	10	33 (18)	.. (1)	..	..	..	..	..	..	..	..	..	..
49·0– 55·9 ..	2 (1)	4 (17)	2 (11)	..	..	..	..	..	..	..	..	..	..
56·0– 62·9 ..	..	.. (3)	1 (46)	.. (6)	..	..	..	..	..	..	..	..	..
63·0– 69·9 ..	..	..	.. (20)	.. (10)	..	..	..	..	..	..	..	..	..
70·0– 76·9 ..	..	..	.. (5)	.. (6)	.. (1)	..	..	..	..	..	..	..	..
77·0– 83·9 ..	..	..	.. (2)	1 (11)	.. (3)	..	..	..	..	..	..	..	..
84·0– 90·9 ..	..	..	..	.. (6)	.. (9)	..	..	..	..	..	..	..	..
91·0– 97·9 ..	..	..	..	..	.. (4)	..	..	..	..	..	..	..	..

98·0–104·9	..	..	..	..	..	.. (4)	.. (4)	..	..	..	..	..	..	..	
105·0–111·9	..	..	..	..	..	.. (3)	.. (10)	..	..	..	..	..	..	..	
112·0–118·9	..	..	..	..	..	.. (2)	..	..	..	..	..	..	..	..	
119·0–125·9	..	..	..	..	..	..	1	2	..	..	..	..	..	..	
126·0–132·9	..	..	..	..	..	..	..	.. (1)	1 *4*	.. *4*	..	..	..	..	
133·0–139·9	..	..	..	..	..	..	..	.. *2*	1 *8*	.. (1) *22*	.. (2) *16*	.. *3*	..	..	
140·0–146·9	..	..	..	..	..	..	..	..	..	.. (1) *4*	2 *5*	2 *4*	1 *1*	..	
147·0–153·9	..	..	..	..	..	..	..	..	..	..	1	.. *1*	2 *1*	1	
Number of fish — Dol net catches, Bombay 265	..	Total	131	116	3	1	..	1	2	2	..	3	2	3	1
Trawler catches, Bombay (214)	..		(1)	(44)	(85)	(39)	(26)	(14)	(1)	..	(2)	(2)	..	..	..
Gill net catches, Bedi *75*	..		..	..	..	..	..	..	*2*	*12*	*30*	*21*	*8*	*2*	..
Combined total 554	..		132	160	88	40	26	15	5	14	32	26	10	5	1
Mean fish size in cm.	..		..	41·8	60·0	74·1	83·1	107·9	127·1	134·7	136·1	138·5	142·0	148·2	149·0

* Figures in brackets denote fish from the trawler catches off Bombay; and figures in Italics denote fish from the Gill-net catches off Bedi (Gulf of Cutch). Figures not marked denote fish from the 'Dol' net catches off Bombay.

juvenile and adolescent 'Koth'* were made, as done by Perlmutter and Clarke (1949) in *Sebastes marinus*. The fish were then grouped into two categories, (i) those with < 10 circuli in the terminal zone of the scale and (ii) those with > 10 circuli in the terminal zone. The width of the sclerites was more or less uniform irrespective of the season when they were formed and the number of circuli in the scale increased with the growth of the fish. Consequently the period, when scales with the smaller counts of circuli (< 10 circuli) in the 'terminal zone' were dominant, would represent the period closely following the formation of an annulus. Curve A in Fig. 1 shows

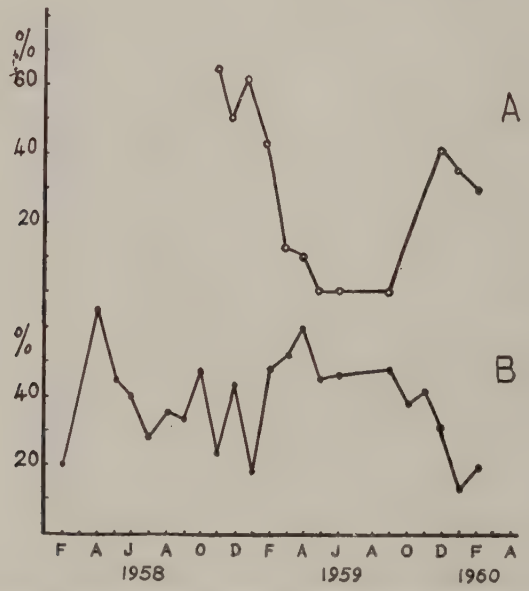

FIG 1. Correlation between period of annuli formation in the scales and period of low feeding activity in *Otolithoides brunneus*. (A) shows monthwise percentage number of juvenile and adolescent fish with < 10 circuli in the 'terminal zone' in their scales. (B) shows monthwise percentage of average fulness of stomach (points method) of juvenile fish from the inshore waters of Bombay.

that this period was between November and February. Studies on the feeding habits of the fish revealed that this period of scale annuli formation as judged from the circuli counts more or less coincides with the periods of low-feeding activity. The average fulness of stomach of juvenile 'Koth' from the inshore catches of Bombay, calculated month-wise, was found to be least during February 1958, December and January in 1958–59 and December,

* The fish attains first maturity at the size of about 120 cm.

TABLE II

Distribution of the first six rings on the otoliths of 'Koth', Otolithoides brunneus *at various size groups.**

Size groups		Number of rings					
		1	2	3	4	5	6
3·0– 6·9 ..		5	..	..	..	..	..
7·0–13·9 ..		61	5	..	..	..	..
14·0–20·9 ..		35	22	..	..	..	..
21·0–27·9 ..		11	20	2	..	..	..
28·0–34·9 ..		..	8 (1)	31	..	..	..
35·0–41·9 ..		..	2	52 (1)	4	..	..
42·0–48·9 ..		..	..	15 (4)	13	.. (1)	..
49·0–55·9 ..		..	..	6 (3)	5 (6)	.. (4)	..
56·0–62·9 ..		..	..	1 (1)	1 (8)	.. (12)	..
63·0–69·9 ..		..	..	..	.. (5)	.. (7)	.. (1)
70·0–76·9 ..		..	..	..	.. (2)	.. (2)	.. (4)
77·0–83·9 ..		..	..	..	..	.. (1)	.. (4)
84·0–90·9 ..		..	..	..	..	..	.. (6)
No. of fish	'Dol' net catches, Bombay 299 ..	112	57	107	23	..	..
	Trawler catches, Bombay 73 ..	..	1	9	21	27	15
	Combined total 372 .. Total	112	58	116	44	27	15
	Mean fish size in cm. ..	13·8	23·4	39·3	45·5	61·5	80·3

* Figures in brackets denote fish from trawler catches off Bombay and figures not marked denote fish from 'Dol' net catches off Bombay.

January and February in 1959–60 (Fig. 1 B). The annual lowering of feeding intensity can thus be made out as a probable cause for the formation of the scale annuli. It is also of interest to note that the period from November

to February happens to be the period of lowest bottom and surface temperatures in the Dwaraka region, where there is a good fishery for 'Koth' (Jayaraman and Gogate, 1957 and Jayaraman *et al.*, 1959).

Otoliths of 372 fish were studied by the method followed by Fairbridge (1951). With a few exceptions all of them showed clear rings which increased progressively in their number with the size of the fish (Pl. III, Fig. 2 and Table II). The otoliths contain concentric opaque and hyaline zones. The concentric hyaline zones were counted as rings. The clearer pattern of rings in the otoliths of younger fish enabled its study better and there was clear indication to show that 2 to 3 rings were formed in the otoliths by the time the scale developed only a single ring. While the otoliths of very small 'Koth' studied showed a clear ring it was evident that the first scale ring appeared only when a much larger size was attained by the fish. A comparison of Tables I and II shows the disparity in the distribution of rings on the scales and otoliths of 'Koth'. The occurrence of more number of rings in the otoliths than on the scales is perhaps an indication as Saetersdal (1953) pointed out that "the otolith is a more sensitive instrument than the scale, and records smaller differences in the conditions of the fish than does the scale". The formation of more than one ring on the otoliths in the first year of life of fishes such as *Clupea pilchardus*, where 2 to 4 rings are formed in the first year, *Pleuronectes platessa* and *Drepanosetta platessoides*, is reported by Kotthaus (1958 and personal communication). The present studies clearly indicate that the scales of 'Koth' are more reliable than the otoliths as age indicators.

I am thankful to Dr. S. Jones and Dr. G. Seshappa for their criticism and encouragement during the course of this work and to W. D. Pachare, Artist-Photographer, T. N. Medical College, Bombay, for photographing the otoliths.

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FIG. 1. Photographs of scales of *Otolithoides brunneus* (scales used as negatives). (*a*) Scale showing 6 rings, ×5. (Total length 125·0 cm. female captured on 6–3–1959 from Dwaraka region by the bull trawlers 'Arnala and Paj'). *T*, terminal zone. (*b*). Scale showing 11 rings, ×4. (Total length 146·5 cm. Sex not known, captured on 30–11–1958 from Satpati—examined at Crawford Market, Bombay.)

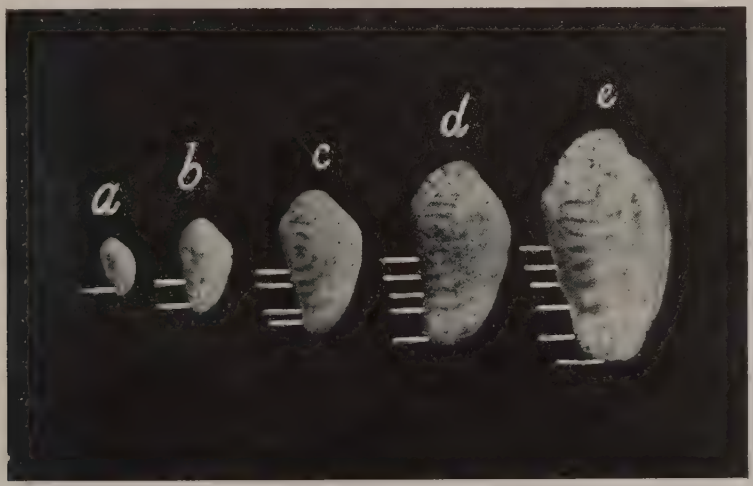

FIG. 2. Photograph of otoliths of *Otolithoides brunneus*, ×1·4. The external sculpturing on the otoliths are seen as shaded markings, which are seen darker at the opaque growth regions and are marked here as rings. The external prominences at the opaque growth regions are clearly seen because of the diffused lighting technique used in photographing these otoliths.

(*a*) Otolith showing one ring—Fish length: 11·2 cm.; (*b*) Otolith showing two rings—Fish length: 20·7 cm.; (*c*) Otolith showing four rings—Fish length: 35·5 cm., male; (*d*) Otolith showing five rings—Fish length: 45·9 cm., female; (*e*) Otolith showing six rings—Fish length: 63·4 cm., male.

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FURTHER OBSERVATIONS ON THE FISHERY AND BIOLOGY OF '*CHOODAI*' (*SARDINELLA* spp.) OF MANDAPAM AREA

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Introduction

The sardines, locally called *Choodai*, constitute one of the important groups of fishes supporting the fisheries of the Mandapam area. *Sardinella albella* and *Sardinella gibbosa* are the two important species forming the fishery. Previous studies on sardines in the area include observations made by Devanesan (1932) on the food and feeding habits and Chacko (1946) on the bionomics of *S. gibbosa*. Investigations have been in progress since 1952 at the Central Marine Fisheries Research Station (Sekharan, 1955 and 1959) on the *Choodai* fishery. The present study was undertaken from May 1958 to March 1960 as a continuation of the work.

Material and Methods

Random samples of *Choodai* from commercial catches were obtained from Pullamadam, Thangachimadam and Dhanushkodi in the Palk Bay and from Rameswaram Road and C.M.F.R.S. area in the Gulf of Mannar. It may be pointed out here that " torch fishing " with handnets were sparingly operated in the fishing centres during the period of study and the gillnets accounted for a very insignificant proportion of the total catch. Bulk of the sardine catch were landed by shore seines operating within two miles from shore. The fishery usually starts in April in the Palk Bay and lasts till October. From November to March it is continued in the Gulf of Mannar coast.

All random samples taken from the commercial catches were measured for length frequency observations and detailed study was done only on selected samples. The standard length, *i.e.*, the length from the tip of the snout to the end of the silvery area on the caudal peduncle was recorded in millimetres. Head length was measured from the tip of the snout to the posterior edge of the operculum. In many cases the fishermen's records of catch have been used while calculating the monthly landings. Gut contents of 580 specimens preserved in 5% formalin as soon as they were landed were studied. After

noting the fulness of the gut the contents were analysed for the various food items present.

Composition of Commercial Landings

(*a*) *Length frequency composition.*—Length frequency data are available for the period between June 1958 and February 1960. Standard length is considered as the linear measurement for this analysis. To minimise the effect of gear selection only shore seine samples are included.

It has been observed earlier that the fishing season was not the same for Palk Bay and Gulf of Mannar. Consequently the size range of fish occurring in the two coasts vary greatly. Figures 1 and 2 illustrate the length frequencies and modes for samples from the two regions. When the fishing started at Palk Bay in June 1958, the size range of *S. albella* was from 35 mm. to 110 mm. standard length, showing two distinct modes. This bi-modality was due to the presence of fish belonging to two age groups, namely the 0-year group and 1-year group. Mode '*a*', for the 0-year group was at 60 mm. in June. At the same time mode '*b*', representing the one-year group, was at 100 mm. Succeeding months showed a progressive growth of mode '*a*' and it had shifted to 85 mm. in October 1958 when the fishery at Palk Bay came to a close. The range of size of the commercial catch in October was from 75 to 100 mm. Mode '*b*' was at 100 mm. in June 1958 and remained constant during July also. Subsequently mode '*b*' showed a backward movement and came down to 95 mm. in August and September. In October it had merged with the size groups in the 0-year group fish. This backward shifting of mode '*b*' might be due to the non-availability in sufficient numbers of larger size groups in the shoals that had entered the fishing grounds.

In October 1958 the fishery had shifted to the Gulf of Mannar coast. The size groups in the commercial catches fall mainly within the limits of 65 to 110 mm. standard length. The dominant size group which was at 85 mm. at the commencement of the season had moved to 90 mm. in November and December 1958 and to 95 mm. in January 1959. At the end of January *S. albella* had ceased to appear in the catches.

In the 1959 season also the length-frequency disposition for the Palk Bay fish showed two separate modes. Fish in mode '*a*' was at 45 mm. in May 1959 and reached to 65 mm. at the end of September. Mode '*b*' was at 95 mm. from May to August and had grown to 100 mm. in September, when the Palk Bay fishery stopped for the season.

Fishing in Gulf of Mannar commenced in November 1959 and the sample obtained at that time showed the major length group to be at 80 mm. This

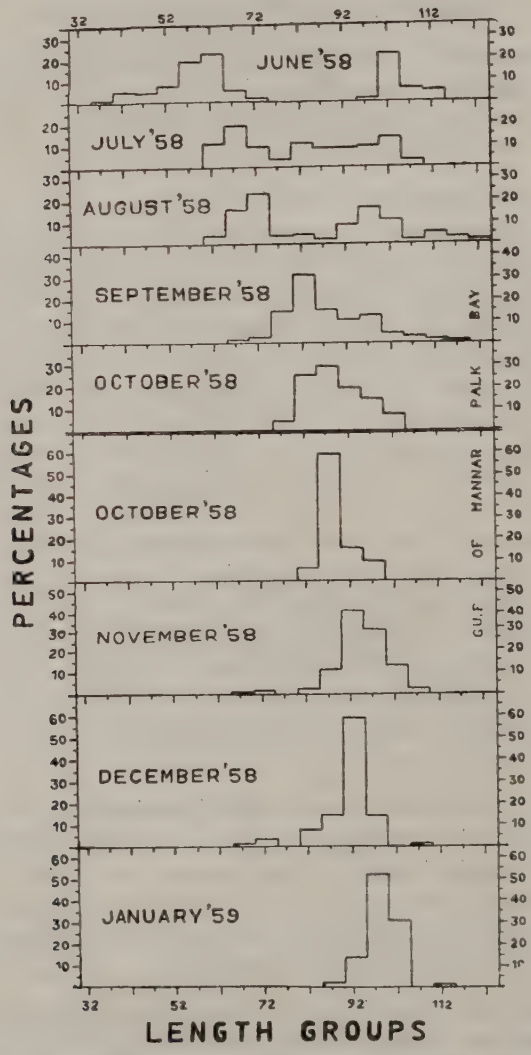

FIG. 1. Length frequency distribution of *S. albella* during 1958–59.

had shifted to 90 mm. in January 1960. After January adequate samples of *S. albella* could not be obtained from the Gulf of Mannar catches.

(*b*) *Age composition.*—Only *Sardinella albella* belonging to 0-year, one-year and two-year groups have been met with in the course of this study. Table I shows the age composition of commercial landings from the two coasts. Well over 50% of the Palk Bay fishery was formed of 0-year group

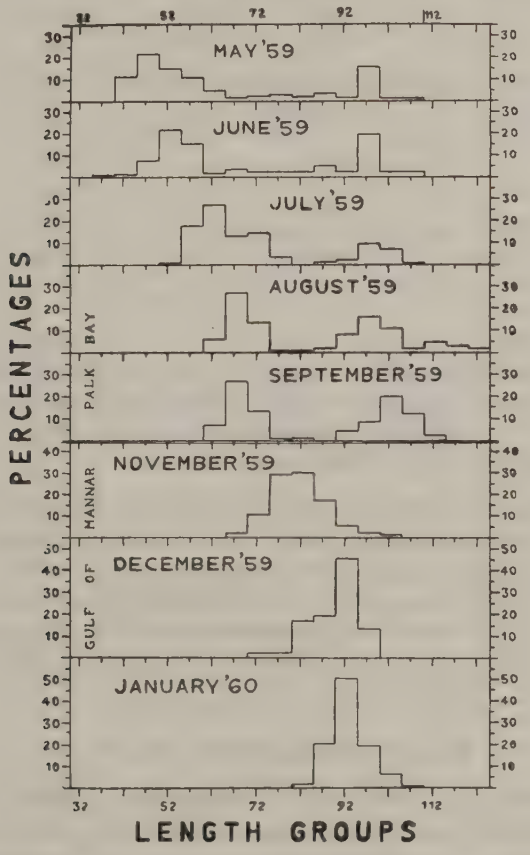

FIG. 2. Length frequency distribution of *S. albella* during 1959-60.

and fish of 1-year and 2-year groups occupied the remaining portion. The Gulf of Mannar fishery was formed only of fish belonging to 0-year group.

Rounsefel and Everhart (1953) point out that fish tend to mingle more or less according to size with different age groups schooling together. However the present knowledge of the behaviour of *S. albella* does not provide

TABLE I

Age composition of commercial catches (in per cent.)

Age group	1958–59 Season		1959–60 Season	
	Palk Bay	Gulf of Mannar	Palk Bay	Gulf of Mannar
0–Year	60·7	100	58·4	100
1–Year	35·3	..	41·6	..
2–Year	4·0	..	..	..
Number of fish examined ..	987	579	659	421

any explanation for the absence of 1-year and 2-year old fish in the Gulf of Mannar commercial catches. Jayaraman (1954) observed marked differences in the values of salinity, dissolved oxygen and nutrient salts between Palk Bay and Gulf of Mannar. Prasad (1956 and 1958) observed variations in the Plankton crop in the two areas.

(*c*) *Sex composition.*—An analysis of the ratio of sexes in the commercial catches shows that there was an initial predominance of females over males up to 80 mm. standard length. Subsequently the sexes tended to be equally represented. The sex composition of the commercial catches was 40·8% females, 31·3% males and 27·9% indeterminates. The large percentage of indeterminates was due to their greater representation (over 50%) in the Palk Bay landings.

RELATIVE ABUNDANCE OF SPECIES

The proportion of *S. albella* and *S. gibbosa* entering into the commercial fishery is determined from information gathered from the catch statistics records maintained by the Central Marine Fisheries Research Station and from the registers of individual fishermen.

An accurate measure of the catch of the two species per unit effort was not obtainable from the commercial catch. Because the fishermen neither employed fixed number of men for each type of unit nor were they able to give adequate information about the effort expended for each operation. Therefore, only the relative abundance of the individual species on the total monthly catch could be made (Table II).

TABLE II

Indices of relative abundance of Sardinella albella *and* Sardinella gibbosa *from Palk Bay and Gulf of Mannar (represents data from Pullamadam, Dhanushkodi, Rameswaram Road and C.M.F.R.S. Area)*

(*a*) *Palk Bay*

Months	1958 Season			1959 Season		
	Index for *S. albella*	Index for *S. gibbosa*	Total fish landed (kg.)	Index for *S. albella*	Index for *S. gibbosa*	Total fish landed (kg.)
April ..	..	..	..	2·3	0·1	84554
May ..	20·6	10·2	95865	39·6	20·9	88514
June ..	52·9	16·4	84578	30·3	7·9	127567
July ..	38·0	7·3	30119	41·4	5·6	85957
August ..	33·4	4·3	24764	43·3	14·8	47463
September ..	44·4	7·5	49831	42·8	6·4	88953
October ..	36·0	17·2	37216	57·1	40·6	26535
Totals ..	37·1	11·5	322373	33·7	10·4	549543

(*b*) *Gulf of Mannar*

Months	1958–59 Season			1959–60 Season		
	Index for *S. albella*	Index for *S. gibbosa*	Total fish landed (kg.)	Index for *S. albella*	Index for *S. gibbosa*	Total fish landed (kg.)
1958						
October ..	15·7	30·7	1789	..	..	..
November	14·8	22·0	1777	7·3	27·5	5187
December	7·9	24·0	18703	16·4	25·1	5395
1959						
January ..	10·2	19·6	25965	1·8	22·0	6569
February	1·7	19·6	94730	0·4	40·5	7236
March ..	5·8	18·2	6580	..	..	..
April ..	2·3	78·8	21260	..	..	..
Totals ..	4·2	27·6	170804	5·8	29·4	24387

Assuming that the commercial catch represent the composition of fish in that area in that period, it is thought that the size of the proportions of a certain species in the total catch could be an index to denote the relative abundance of that species in that area at that period. The index of relative abundance therefore is

$$A = \frac{T}{W} \times 100$$

where A is the index of relative abundance, T, total catch of a particular species and W is the total weight of the fish landed.

It may be seen from Table II that in the Palk Bay *S. albella* was represented more than *S. gibbosa* in the catches. The greatest amount of *S. albella* was taken during the months of May and June. The index for *S. gibbosa* was lower in comparison with that for *S. albella*. A reverse trend has been evident in the Gulf of Mannar, where, as against the observations in Palk Bay, *S. albella* was poorly represented whereas *S. gibbosa* was relatively abundant.

The abundance of fish populations at a given period may be controlled by physical, chemical and biological factors of the environment. The periodical fluctuations in catch of the two species can be explained in terms of environmental influence on the fish at various stages of its life. On the other hand, the differences in relative abundance of *S. albella* and *S. gibbosa* in the two coasts indicate not only that the factors favouring the availability of rich *S. albella* stock in the Palk Bay were inoperative in the Gulf of Mannar, but that each species entered the fishery independent of the other.

Rate of Growth

The mean length of different age groups of *S. albella* for the successive months are contained in Table III. Growth curves for the two seasons between June 1958 and Janaury 1960 are shown in Fig. 3. Three age groups, 0-year, 1-year and 2-year groups, were noted during the 1958–59 fishing season. However, fish in the 2-year group was comparatively few in the commercial catches and had occurred only at Dhanushkodi. Catches of the 1959–60 season comprised only of fish belonging to 0-year and 1-year groups.

It will be apparent from a study of Table III, that, the 1958 year class had a higher growth rate than fish of the 1959 year class. The mean length for the 1958 year class was at 61 mm. in June 1958 and had shifted to 98 mm. at the end of January 1959 indicating a growth of 37 mm. for that period. On the other hand, the 1959 year class fish was at 51 mm. in

TABLE III

Mean length in millimetres of successive age groups examined (All samples are combined)

Months	1958–59 Season			1959–60 Season		
	Age groups			Age groups		
	0–year	1–year	2–Year	0–year	1-year	2-year
March ..	..	..	..	..	93·74	..
April ..	..	..	..	..	..	..
May ..	..	..	..	50·80	93·61	..
June ..	60·99	102·70	111·33	52·64	91·17	..
July ..	74·47	98·30	..	61·98	98·21	..
August	68·24	97·57	115·10	67·92	101·08	..
September	82·44	97·39	115·20	67·94	101·39	..
October	88·79	..	..	..	..	..
November	93·99	..	..	81·11	..	..
December	90·22	..	..	83·03	..	..
January	97·91	..	..	92·48	..	..

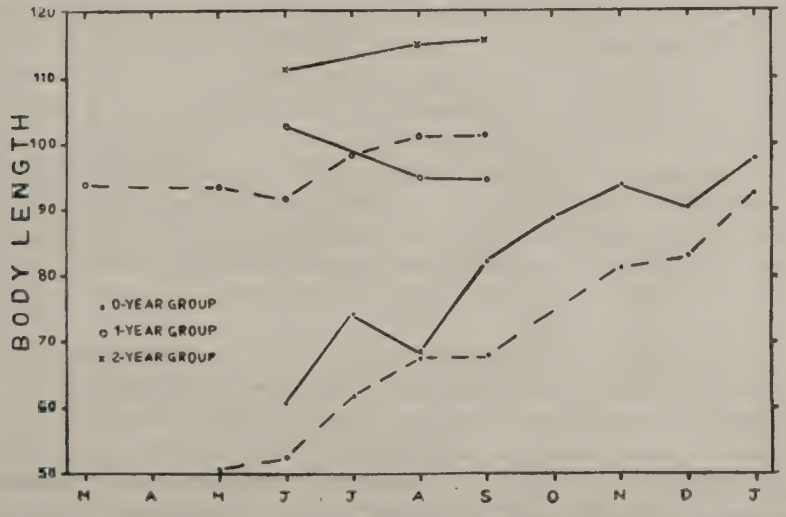

FIG. 3. Rate of growth in length of *S. albella* during 1958–60. Continuous and broken lines represent 1958–59 and 1959–60 seasons respectively.

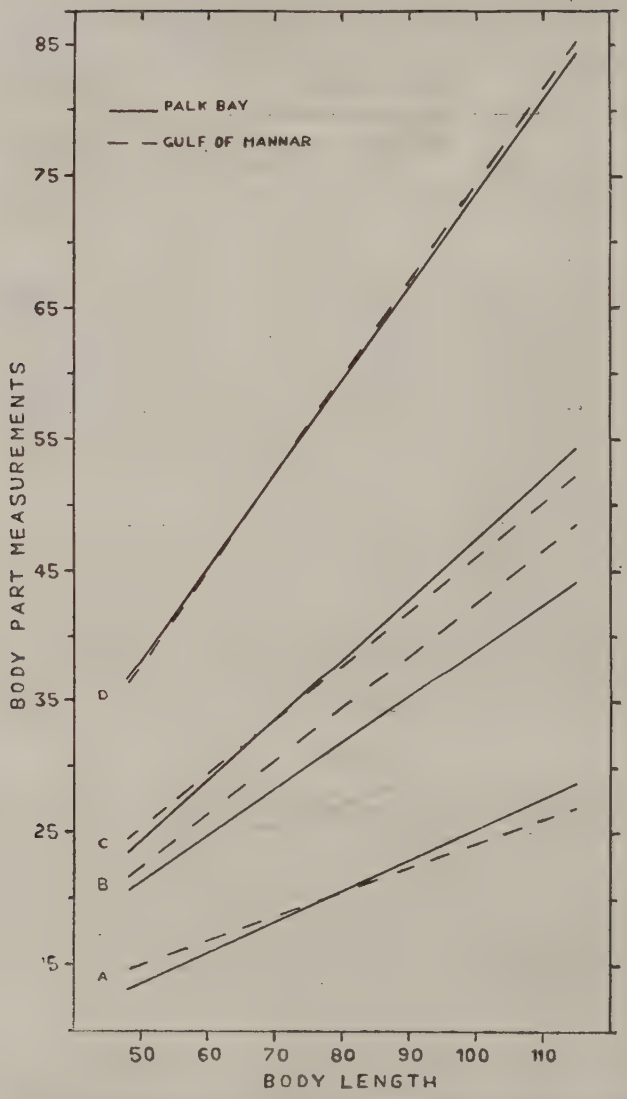

FIG. 4. Regression of different body measurements on standard length of *S. albella* from Palk Bay and Gulf of Mannar (A, head length ; B, snout to dorsal insertion ; C, snout to ventral insertion; D, snout to anal insertion).

May 1959 and had grown to 92 mm. at the end of January 1960 showing an increase in length of 33 mm. in nine months. During June 1958 fish of the 1957 year class had a mean length of 102·7 mm. Mean length values for this group came down to 97·6 mm. in August and to 97·4 mm. in October 1958. After October the 1957 year class did not appear in the fishery. The gill net catches of March 1959 contained mainly fish of the 1958 year group. At that time the mean length of this group was 93·7 mm. This had shifted to 101·4 mm. in September, when the 1-year group stopped entering the fishery of 1959–60 season. The 2-year fish that were landed in the commercial catches had the mean length of 111·3 mm. in June 1958. It had grown to 115·2 mm. at the close of September 1958.

Homogeneity of Samples

The commercial catches of *S. albella* from Palk Bay and Gulf of Mannar show differences in size-group composition, in the occurrence of various age groups and in the relative abundance in relation to the other important species, *S. gibbosa*, in the fishery. It is important to determine whether the fish occurring in the two coasts belong to a homogeneous population or are derived from different racial stocks. Morphometric characters like head length, snout to dorsal insertion, snout to ventral insertion and snout to anal insertion of *S. albella* collected during 1959–60 were compared by methods of regression analysis similar to the methods employed by Godsil (1948), Schaefer (1955), Sarojini (1957 and 1958) and Pillai (1957) in racial studies. Comparisons were made based on samples from Pullamadam and Dhanushkodi in the Palk Bay and from Rameswaram Road and C.M.F.R.S. area in the Gulf of Mannar. Due to change in fishing seasons samples of fish of the same length range were not available from all the localities. Samples from Dhanushkodi, Rameswaram Road and C.M.F.R.S. area had little difference in size range. However, the mean size of the Pullamadam sample, which is composed mainly of fish of smaller size groups, was far below the mean size of fish from other localities.

Altogether 497 fish were observed for morphometric analysis. Significance of differences between samples were tested by the method of analysis of covariance (Snedecor, 1946). Linear regressions were employed in relating the independent variable (standard length) to the dependent variable (various body lengths). Scatter diagrams of the measurements of each sample, after being fitted with the line $\hat{Y} = a + bX$ were checked for linearity. Tables IV to VI show the details relating to regression analysis.

TABLE IV

Statistics describing regressions of body measurements of Sardinella albella *from Mandapam area*

(Independent variable x = Standard length)

	Dependent variable y	N	$\bar{x}$	$\bar{y}$	Sx^2	Sy^2	Sxy	b	a
(*a*)	*Pullumadam sample* Head length ..	121	63·5123	16·7024	6808·2315	451·2893	1669·4477	·2452	1·1292
	Snout to insertion of dorsal ..	121	63·5123	27·3388	6808·2315	1325·1075	2931·0000	·4305	·0032
	Snout to insertion of ventral ..	121	63·5123	39·5123	6808·2315	1624·2315	3252·2315	·4776	·1789
	Snout to insertion of anal ..	121	63·5123	46·8016	6808·2315	3959·2397	5008·2973	·7356	·0884
(*b*)	*Dhanushkodi sample* Head length ..	108	93·0000	23·5000	20506·0000	1163·0000	4733·0000	·2308	2·0449
	Snout to insertion of dorsal ..	108	93·0000	39·9629	20506·0000	3803·8519	8801·0000	·4291	·0566
	Snout to insertion of ventral ..	108	93·0000	44·2592	20506·0000	4498·7408	9189·0000	·4481	2·5859
	Snout to insertion of anal ..	108	93·0000	69·7129	20506·0000	12016·1019	15532·0000	·7574	·7160
(*c*)	*Rameswaram Road sample* Head length ..	102	91·7647	22·7549	1914·3530	98·8726	371·1177	·1938	4·9710
	Snout to insertion of dorsal ..	102	91·7647	39·2058	1914·3530	422·6765	791·9412	·4136	1·2153
	Snout to insertion of ventral ..	102	91·7647	42·9019	1914·3530	395·0197	754·6471	·3942	6·7100
	Snout to insertion of anal ..	102	91·7647	68·6274	1914·3530	1211·8432	1411·0589	·7370	·9785
(*d*)	*C.M.F.R.S. area sample* Head length ..	166	89·0542	22·1506	7212·5121	277·2350	1292·6446	·1792	6·2010
	Snout to insertion of dorsal ..	166	89·0542	38·2108	7212·5121	1223·6205	2873·1025	·3983	2·7406
	Snout to insertion of ventral ..	166	89·0542	41·4578	7212·5121	1385·2049	2991·8796	·4148	4·5271
	Snout to insertion of anal ..	166	89·0542	66·1325	7212·5121	3925·0844	5139·8073	·7126	2·6725
(*e*)	*Pooled Palk Bay sample* Head length ..	229	77·4192	19·9082	76933·7557	4251·0743	17840·8035	·2318	1·9625
	Snout to insertion of dorsal ..	229	77·4192	33·2925	76933·7557	14283·3974	32974·9127	·4286	·1107
	Snout to insertion of ventral ..	229	77·4192	36·9956	76933·7557	16906·9564	35573·4193	·4623	1·2048
	Snout to insertion of anal ..	229	77·4192	57·6069	76933·7557	45930·6289	54614·2808	·7098	2·6548
(*f*)	*Pooled Gulf of Mannar sample* Head length ..	268	90·0858	22·3805	9591·0262	399·1792	1767·2463	·1842	5·7867
	Snout to insertion of dorsal ..	268	90·0858	38·5895	9591·0262	1708·8508	3835·4403	·3998	2·5732
	Snout to insertion of ventral ..	268	90·0858	42·0074	9591·0262	1911·8508	3993·8284	·4164	4·4957
	Snout to insertion of anal ..	268	90·0858	67·0820	9591·0262	5530·1940	6978·1120	·7275	1·5446

First, the samples from the two localities in Palk Bay were compared. It can be seen from Table V that regression analysis did not show any significant difference between the samples from Pullamadom and Dhanushkodi even in spite of the great size difference of fish in the two samples. In the second place, comparisons were made between the two samples from the Gulf of Mannar. No significant difference was noticed in the regression of body characters from samples of fish from Rameswaram Road and C.M.F.R.S. area. Based on the above comparisons it may be assumed that the Palk Bay samples are all derived from a single homogeneous stock and, similarly, the two samples from the Gulf of Mannar belong to one single racial stock. The pooled samples of Palk Bay and Gulf of Mannar were then compared. The regression analysis showed that they are significantly different. Individual samples of each locality were then compared with the individual samples of the other locality. The results of the comparisons between individual samples are given in Table VI.

The Pullamadam sample shows significant statistical difference with the Rameswarm Road sample in the regressions of head length and snout to ventral insertion. In the regressions of snout to dorsal insertion and snout to anal insertion the differences are not significant. Significant statistical differences are noticed in the regressions of head length, snout to dorsal insertion and snout to ventral insertion when the Pullamadam sample is compared with fish from C.M.F.R.S. area. Pullamadam and C.M.F.R.S. area samples do not show any significant difference in regard to the regression of snout to anal insertion. Dhanuskhodi sample differs significantly from Rameswaram Road sample only in the regression of head length on body length. On the other three characters the differences are statistically non-significant. Dhanushkodi fish differs significantly from the C.M.F.R.S. area sample in three characters—head length, snout to dorsal insertion, and snout to anal insertion. Only in the case of snout to insertion of ventral fin the difference between Dhanushkodi and C.M.F.R.S. area fish is not significant.

It appears that Palk Bay fish are different from those of the Gulf of Mannar coast as is seen from foregoing analysis. Even though the fish samples in the two localities in Palk Bay were of different size class, the regression analysis did not show any significant difference, but comparison betwen localities between Palk Bay and Gulf of Mannar showed significant difference. It is likely that some of the differences between fish from Palk Bay and Gulf of Mannar could have originated from the changes in the environment.

TABLE V

Test of heterogeneity of regressions within samples of Sardinella albella *from Mandapam area*

Characters	Deviations from average total regressions		Deviations from individual regressions within samples			Difference			Observed F	5%
	Degrees of freedom	Sum of squares	Degrees of freedom	Sum of squares	Mean square	Degrees of freedom	Sum of squares	Mean square		
(*a*) *Pullamadam and Dhanushkodi samples*										
Head length ..	226	113·5575	225	112·4978	·4999	1	1·0597	1·0597	2·1198	3·89
Snout to insertion of dorsal ..	226	149·8346	225	149·8257	·6658	1	·0089	·0089	74·8089	254
Snout to insertion of ventral ..	226	456·1374	225	451·7024	2·0075	1	4·4350	4·4350	2·2092	3·89
Snout to insertion of anal ..	226	529·0412	225	526·6093	2·3404	1	2·4319	2·4319	1·0390	3·89
(*b*) *Pullamadam and Rameswaram Road samples*										
Head length ..	220	72·7923	219	68·8513	·3143	1	3·9410	3·9410	12·5389	3·89
Snout to insertion of dorsal ..	220	158·7721	219	158·3473	·7230	1	·4248	·4248	1·7019	254
Snout to insertion of ventral ..	220	178·6183	219	168·2039	·7680	1	10·4144	10·4144	13·5604	3·89
Snout to insertion of anal ..	220	446·7793	219	446·7761	2·0400	1	·0032	·0032	637·5000	254
(*c*) *Pullamadam and C.M.F.R.S. area samples*										
Head length ..	284	102·7379	283	87·4878	·3091	1	15·2501	15·2501	49·3371	3·88
Snout to insertion of dorsal ..	284	146·0305	283	142·4086	·5032	1	3·6219	3·6219	7·1977	3·88
Snout to insertion of ventral ..	284	228·6336	283	214·7891	·7589	1	13·8445	13·8445	18·2428	3·88
Snout to insertion of anal ..	284	539·2049	283	537·3523	1·8987	1	1·8526	1·8526	1·0248	254

(d)	*Dhanushkodi and Rameswaram Road samples*										
	Head length ..	207	99·8919	206	97·5015	·4733	1	2·3904	2·3904	5·0504	3·89
	Snout to insertion of dorsal ..	207	182·0203	206	181·5994	·8815	1	·4209	·4209	2·0943	254
	Snout to insertion of ventral ..	207	483·6552	206	478·5671	2·3231	1	5·0881	5·0881	2·1902	3·89
	Snout to insertion of anal ..	207	424·0769	206	423·3524	2·0551	1	·7245	·7245	2·8365	254
(e)	*Dhanushkodi and C.M.F.R.S. area samples*										
	Head length ..	271	130·3385	270	116·1380	·4301	1	14·2005	14·2005	33·0167	3·88
	Snout to insertion of dorsal ..	271	170·7342	270	165·6587	·6135	1	5·0755	5·0755	8·2730	3·88
	Snout to insertion of ventral ..	271	531·0672	270	525·1523	1·9450	1	5·9149	5·9149	3·0410	3·88
	Snout to insertion of anal ..	271	524·6440	270	513·9286	1·9034	1	10·7154	10·7154	5·6296	3·88
(f)	*Rameswaram Road and C.M.F.R.S. area samples*										
	Head length ..	265	72·8157	264	72·4915	·2745	1	·3242	·3242	1·1810	3·89
	Snout to insertion of dorsal ..	265	174·5381	264	174·1823	·6597	1	·3558	·3558	1·8541	254
	Snout to insertion of ventral ..	265	242·2965	264	241·6538	·9153	1	·6427	·6427	1·4241	254
	Snout to insertion of anal ..	265	435·0012	264	434·0954	1·6443	1	·9058	·9058	1·8153	254
(g)	*Pooled Palk Bay and Pooled Gulf of Mannar samples*										
	Head length ..	494	206·7218	493	187·3689	·4206	1	19·3529	19·3529	46·1260	3·86
	Snout to insertion of dorsal ..	494	331·9708	493	324·9389	·6591	1	7·0319	7·0319	10·6689	3·86
	Snout to insertion of ventral ..	494	724·9496	493	696·6156	1·4130	1	28·3340	28·3340	20·0523	3·86
	Snout to insertion of anal ..	494	7616·4726	493	7614·1071	15·4444	1	2·3655	2·3655	6·5290	254

Food and Feeding Habits

The food contents were very often in the form of a semi-digested slimy mass and so only a rough generic identification of the components were possible. The following food organisms were found in the gut contents of *S. albella*: *Rhyncalanus*, *Labidocera*, *Eucalanus*, *Euterpina*, *Lucifer*, *Acetes*, *Mysis*, *Megalopa* larva, bivalve shelled larva, *Pteropoda*, flat fish larva, *Thallasiothrix*, *Bacteriastrum* and *Triceratium*. Copepods form the bulk of the gut contents. Bapat and Bal (1950) showed that larva and post-larva of *S. albella* feed mainly on copepods. Vijayaraghavan (1959) observed that *S. albella* is a surface feeder and plankton predator. The prevalence of larger crustaceans like *Lucifer* and *Acetes* shows that the fish to a certain extent is not an indiscriminate filter feeder.

Table VI

Differences in morphometric characters between localities

Localities	Characters			
	Head length	Snout to insertion of dorsal	Snout to insertion of ventral	Snout to insertion of anal
Pullamadam and Dhanushkodi ..	NS	NS	NS	NS
Pullamadam and Rameswaram Road	S	NS	S	NS
Pullamadam and C.M.F.R.S. area	S	S	S	NS
Dhanushkodi and Rameswaram Road	S	NS	NS	NS
Dhanushkodi and C.M.F.R.S. area	S	S	NS	S
Rameswaram Road and C.M.F.R.S. area	NS	NS	NS	NS

S, Significant; NS, Non-Significant.

Prediction

Movement of shoals towards the inshore waters is generally predicted by fishermen based on the direction and intensity of the prevailing winds. During May to September the wind blows from the south and when there is a strong south-northerly wind *Choodai* from the northern waters move southwards and enter into the Palk Bay fishing waters. South-westerly wind moves the fish away from the fishing grounds. During October to April the wind blows from the north. When there is strong wind in north-southerly direction

fish shoals come close to the shore in the Gulf of Mannar coast. When the incidence and velocity of winds are high, mostly connected with the north-east and south-west monsoons, *Choodai* are absent from the fishing grounds.

Summary

The paper deals with a general account of the *Choodai* fishery in the Mandapam area, with particular reference to data on *Sardinella albella* collected during May 1958 to March 1960. Age and size groups of fish occurring in the commercial landings of Palk Bay and Gulf of Mannar are discussed. Old large fish and young small fish predominated in commercial catches from the Palk Bay; commercial catches from the Gulf of Mannar are mainly composed of young fish of medium size.

There is a slight predominance of females over males up to 80 mm. The sex composition of catches during the period may be stated as 40·8% females, 31·3% males and 27·9% indeterminates.

The index of relative abundance of *Sardinella albella* is more than that of *Sardinella gibbosa* in the Palk Bay; in the Gulf of Mannar *S. gibbosa* is relatively more abundant than *S. albella.*

Growth rates of different age groups are discussed. Slight difference in the growth rates of 1958 and 1959 year classes are indicated.

Morphometric characters like head length, snout to insertion of dorsal, snout to insertion of ventral and snout to insertion of anal of fish collected from the two coasts during 1959–60 season are compared by methods of regression analysis. It is suggested that difference observed between *Sardinella albella* from Palk Bay and Gulf of Mannar centres may have originated from the changes in the environment.

Sardinella albella is a plankton feeder. Copepods form the major food item. The prevalence of larger crustaceans like *Lucifer* and *Acetes* suggests that the fish is not an indiscriminate filter feeder.

Wind direction and velocity appear to be important in contributing to good fishery of *Choodai* in the region.

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A PRELIMINARY STUDY OF THE JUVENILE FISHES OF THE COASTAL WATERS OFF MADRAS CITY

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Introduction

It has generally been observed that in the commercial catches along the Madras coast very young stages of fish occur in enormous numbers during certain months. The present paper deals with the periodicity in the post-larval and juvenile bony fishes obtained from March 1954 to July 1955 collected from the fishing centres at Triplicane North and South, Ayodhya-kuppam, Nochikuppam, Santhome, Kanniappanagar and Royapuram. The majority of the species being of great commercial importance, it is hoped that a record of their very young stages, apparently not older than a few months, as judged by their very small size of about few cm. in length, will help in fixing the approximate period of their breeding and in facilitating interpretation of the different size classes, usually obtained in the commercial catches. Further, it is well known that information on the fluctuations in the abundance of post-larvæ of any commercial fish is of value in determining the magnitude of the forthcoming fisheries.

Methods of Study

In March and April when the young fishes were landed in abundance in the shore-seines operated along the coastal waters of March, 18 samples were collected at random during 1954 and 16 samples during 1955. The juvenile fishes were generally found mixed up with the adults of whitebait, *Anchoviella commersonii*, which formed the main fishery during these months. A few samples of juveniles were collected in other months also when they occurred in fairly large numbers in shore-seines, boat-seines or bag nets, operated on the coast for various food fishes. Altogether 9,282 specimens representing 73 species under 40 families were measured for their total length and arranged in groups of 1 cm. intervals. Their number, range in size and the major size groups are given in Table I. Early growth rate of some species was studied when they occurred in the samples in consecutive months. The feeding habits have been determined by a study of the stomach contents.

TABLE I

*Juvenile fishes of the Madras Coast**

Species	Months of Occurrence	Size range and major group in brackets—Total length in cm.		Number of specimens examined		Food components
		1954	1955	1954	1955	
Family ELOPIDÆ						
1. *Elops indicus* (Forskål)	April	5–6	..	1	4	Chiefly crustaceans as prawn larvæ and *Acetes indicus* along with bundles of setæ as of polychæte worms
Family CLUPEIDÆ						
2. *Sardinella fimbriata* (Valenciennes)	March and April	4–10 (6)	4– 9 (6)	55	1	Predominantly photoplanktonic organisms, a few copepods and other crustaceans
3. *Sardinella sirm* (Walbaum)	March and April	3– 6 (5)	3–11 (5)	4	203	Phytoplanktonic organisms, a few copepods, other small crustaceans, lamellibranch larvæ and gastropod larvæ
4. *Ilisha indica* (Swainson)	March and April	7– 8 (6)	4– 7 (6)	2	8	Chiefly copepods and a few mysids
5. *Opisthopterus tardoore* (Cuvier)	June	..	3– 8 (6)	..	10	Stomatopod larvæ, prawn larvæ amphipods and mysids

Family DUSSUMIERIIDÆ						
6. *Dussumieria hasseltii* (Bleeker)	March and April	4–10 (5)	5– 9 (7)	79	22	Crustaceans as zœa larvæ, amphipods and copepods
	†December	4– 5 (4)	..	21	..	
	†May and June	6– 7 (7)	..	39	..	
Family DOROSOMATIDÆ						
Sub-family Dorosomatinæ						
7. *Anadontostoma chacunda* (Hamilton Buchanan)	April	5– 6	..	1	..	Prawn larvæ, a few copepods and other crustaceans
Family ENGRAULIDÆ						
8. *Thrissocles mystax* (Bloch and Schneider)	April	4–7	..	2	..	Prawn larvæ, amphipods and a few other crustaceans
9. *Thrissocles setirostris* (Broussonet)	April	7–8	5–8 (8)	1	4	Crustacean food consisting of amphipods, zœa larvæ and *Acetes*
Family CHIROCENTRIDÆ						
10. *Chirocentrus dorab* (Forskål)	March and April	5–12 (7)	5–12 (8)	84	64	*Anchioviella* sp. juvenile *Lactarius lactarius*, young ones of other fish and also small dorabs
			12–24	..	14	
Family SYNODONTIDÆ						
11. *Saurida tumbil* (Bloch)	March and April	7–9 (9)	12	3	1	Young fish and copepods
Family EXOCŒTIDÆ						
12. *Parexocœtus brachypterus* (Rich.)	January	..	6–13 (9)	..	49	Amphipods, copepods, other crustaceans and bits of filamentous algæ

* All obtained in the shore seine catches except otherwise indicated.

† Catch obtained in boat-seines.

TABLE I—(*Contd.*)

Species	Months of Occurrence	Size range and major group in brackets—Total length in cm.		Number of specimens		Food components
		1954	1955	1954	1955	
13. *Cypselurus spilopterus* (Cuvier and Valenciennes)	March and April	4–6	8–10 (8)	2	8	*Acetes indicus*, young prawns, mysids and copepods
Family POLYNEMIDÆ						
14. *Polynemus indicus* (Shaw)	March and April	2–8 (4)	6–10 (8)	32	53	Prawn larvæ, mysids and amphipods
15. *Polynemus sextarius* (Bloch and Schneider)	April	3–9 (7)	2–5 (4)	56	81	Copepods, crustacean larvæ, *Acetes indicus* amphipods and polychæte worms
	June	..	4– 8 (5)	..	84	
	†July	..	4–10 (5)	..	146	
16. *Polynemus sexfilis* (Valenciennes)	March and April	..	5–9 (6)	..	7	Chiefly crustacean food, young prawns, *Acetes*, copepods and zœa larvæ
Family SPHYRÆNIDÆ						
17. *Sphyræna jello* (Cuvier Valenciennes)	March and April	5–7 (6)	6– 8 (6)	10	9	Chiefly young bony fishes, also pteropods, lamellibranch larvæ and gastropod larvæ
18. *Sphyræna obtusata* (Cuvier Valenciennes)	March and April	4–11(6)	5–12 (6)	78	6	Chiefly young bony fish, also copepods, cirrepede larvæ, pteropods, lamellibranch larvæ, gastropod larvæ and few polyzoans

Family MUGILIDÆ						
19. *Mugil* sp.	March and April	3–6 (4)	6–7 (7)	78	3	Large amounts of detritus along with phytoplanktonic organisms, copepods and foraminiferan shells
Family THERAPONIDÆ						
20. *Therapon theraps* (Cuvier)	March	4–6 (5)	..	14	1	Post-larval fishes, young prawns and other crustaceans
21. *Therapon jarbua* (Forskål)	March and April	..	5–6	..	1	Chiefly fish food, also small numbers of amphipods, copepods and lamellibranch larvæ
Family PRIACANTHIDÆ						
22. *Priacanthus hamrur* (Forskål)	March and April	..	5–9 (6)	..	2	Young prawns, other crustaceans and tubiculous worms
Family CARANGIDÆ						
23. *Megalaspis cordyla* (Linnaeus)	April	..	6– 8 (8)	..	3	Post-larval fishes, young prawns and other crustaceans
24. *Decapterus russelli* (Ruppell)	March and April	..	4–12 (10)	..	115	Chiefly crustaceans as *Acetes indicus* and copepods
25. *Selar mate* (Cuvier)	March and April	..	2–12 (8)	..	248	Young prawns, *Acetes indicus* and copepods
26. *Caranx carangus* (Bloch)	March and April	..	5– 7 (6)	..	10	Stomatopod larvæ, other crustaceans and tubiculous polychætes
27. *Alectis indica* (Ruppell)	March and April	4–5	3– 6 (4)	3	5	Zœa larvæ, amphipods cirrepede larvæ and copepods
28. *Carangoides armatus* (Forskål)	April	..	6– 7	..	2	Post-larval fishes and crustaceans as prawn larvæ
29. *Carangoides malabaricus* (Bloch)	March and April	..	2– 9 (9)	..	17	Post-larval bony fishes and crustaceans like prawn larvæ and *Acetes*

TABLE I (*Contd.*)

Species	Months of Occurrence	Size range and major group in brackets—Total length in cm.		Number of specimens examined		Food components
		1954	1955	1954	1955	
30. *Atropus atropus* (Bloch)	March and April	2–8 (5)	..	37	6	..
31. *Chorinemus tol* (Cuvier)	March and April	2–7 (4)	2– 6 (5)	82	38	Post-larval stages of bony fishes as *Lactarius lactarius* and *Anchoviella* sp. also prawn larvæ, *Acetes indicus*, amphipods and lamellibranch larvæ in small numbers
32. *Trachinotus blochi* (Lacépède)	March and April	5–12 (6)	5–7 (6)	41	3	Young ones of *Hippa* (*Emerita*) along with other crustaceans
Family LACTARIIDÆ						
33. *Lactarius lactarius* (Schneider)	March and April	2–9 (6)	2– 6 (3)	52	270	*Acetes indicus* and other crustaceans like prawn larvæ
			2– 5 (4)	..	81	
	June	..	3– 9 (6)	..	21	
Family APOGONIDÆ						
34. *Archamia macroptera*	March and April	5–6	5–7	1	2	Post-larval fishes, young prawns, crustacean larvæ, copepods and mysids
35. *Apogon lateralis* (Bleeker)	March and April	4–5	..	1	..	Amphipods and other small crustaceans
36. *Apogon frenatus* (Valenciennes)	March and April	3–4	6– 8	1	3	Chiefly young prawns, also copepods, other crustaceans and post-larval bony fishes

Family LEIOGNATHIDÆ						
37. *Leiognathus insidiator* (Bloch)	March and April	2–7 (3)	2– 9 (3)	31	65	Chiefly copepods and other crustaceans, also polyzoans
38. *Leiognathus ruconius* (Hamilton Buchanan)	March and April	2–6 (4)	2– 7 (4)	21	114	Mainly copepods also cirrepede larvæ, a few other small crustaceans and larvæ of lamellibranchs
39. *Leiognathus splendens* (Cuvier)	March and April	2–6 (3)	3– 8 (4)	61	118	Copepods and phytoplanktonic organisms
40. *Leiognathus fasciatus* (Lacépède)	March and April	2–4 (3)	3– 6 (4)	81	508	Copepods and other small crustaceans
41. *Leiognathus equulus* (Forskål)	March and April	..	3– 8 (4)	..	108	Chiefly copepods, also cirrepede larvæ, lamellibranch larvæ, gastropod larvæ and phytoplanktonic organisms.
42. *Gazza minuta* (Bloch)	March and April	3–7 (6)	2–10 (3)	101	767	Copepods, other crustaceans and pteropods like *Creseis*
Family GERRIDÆ						
43. *Gerres setifer* (Hamilton Buchanan)	March and April	2–6 (4)	5– 7 (6)	9	15	*Acetes indicus*, amphipods, copepods and other crustaceans
44. *Gerres abbreviatus* (Bleeker)	March and April	3–6 (4)	..	109	..	Mainly crustaceans, with copepods dominating. Remains of *Acetes*, amphipods and polychæte worms were present in small quantities
Family MULLIDÆ						
45. *Upeneus sulphureus* Cuvier	March and April	4–8 (6)	4– 9 (8)	76	183	*Acetes cindius*, copepods and other crustaceans
46. *Upeneus tæneopteris* Cuvier	April	..	5– 9 (7)	..	41	*Acetes indicus*, *Lucifer* copepods and other crustaeeans as prawn larvæ

TABLE I—(*Contd.*)

Species	Months of Occurrence	Size range and major group in brackets—Total length in cm.		Number of specimens examined		Food components
		1954	1955	1954	1955	
47. *Parupeneus indicus* (Shaw)	‡May	..	4– 6 (5)	..	4	Chiefly copepods, *Acetes indicus* and other small crustaceans
Family LUTIANIDÆ						
48. *Lutianus kasmira* (Forskål)	March and April	3–5 (4)	2– 3	38	46	Masses of tubiculous polychæte worms
49. *Lutianus lineolatus* (Ruppell)	March and April	..	3–10 (5)	..	137	Copepods, zœa larvæ, lamellibranch larvæ and gastropod larvæ
Family LETHRINIDÆ						
50. *Lethrinus nebulosus* (Forskal)	March and April	7–9	5– 9	2	4	Young prawns and Copepods
Family NEMIPTERIDÆ						
51. *Nemipterus japonicus* (Bloch)	March and April	3–8 (4)	9–10	25	4	Chiefly prawn larvæ and stomatopod larvæ, also some copepods and amphipods
Family POMODASYIDÆ						
52. *Pomodasys maculatus* (Bloch)	March and April	3–5 (5)	2– 6 (5)	8	196	*Acetes indicus*, *Lucifer*, copepods and cirrepede larvæ
Family SCIÆNIDÆ						
53. *Otolithus* sp.	March and April	3–9 (9)	3– 8 (5)	17	15	*Acetes indicus*, amphipods, copepods and polychæte worms
	June	..	3–12 (5)		8	
54. *Johnius belengeri* (Cuvier)	April	2–7 (3)	2– 4 (3)	52	36	Post-larval bony fishes, young prawns, amphipods, copepods and polychæte worms
	June	..	3– 9 (6)	..	12	
55. *Sciæna dussumeri* (Cuvier and Valenciennes)	April	8–9	2– 6 (3)	1	4	Polychæte worms, copepods and other crustaceans
Family DREPANIDÆ						
56. *Drepane punctata* (Linnaeus)	April	..	4– 6	..	2	Exclusively nemertine worms

Family SIGANIDÆ						
57. *Teuthis javus* (Linnaeus)	March and April	2–7 (3)	2– 6 (3)	240	2083	Phytoplanktonic organisms, bits of algal filaments, copepods and cirrepede larvæ
Family ACANTHURIDÆ						
58. *Acanthurus matoides* (Cuvier nad Valenciennes)	March and April	4–6	3– 6	6	14	Composed of detritus in which no food components are distinguishable
Family SCORPÆNIDÆ						
59. *Pterois russelli* (Bennett)	March and April	3–4	3– 4	2	1	Young prawns, mysids, amphipods and copepods
Family TRICHIURIDÆ						
60. *Trichiurus haumela* (Forskål)	March and April	9–10 13–27	8–10 14–25	10	16	Young and post-larval bony fishes and crustaceans like young prawns
Family SCOMBRIDÆ						
61. *Rastrelliger kanagurta* (Cuvier)	February	..	5–11 (9)	..	23	(*a*) In juveniles up to 8 cm. preponderance of phytoplanktonic organisms with fair numbers of small zooplanktonic organisms
	March	13–15 (13)	4–10 (8)	172	44	
	April	4–12 (7)	4–12 (8)	210	316	
	May	4–6 (5)	..	90		
	June	..	11–14 (13)	..	80	
	July	..	9–17 (11)	..	34	(*b*) In juveniles between 9 and 10 cm. predominantly post-larval fishes, stomatopod larvæ and other crustaceans, with very little phytoplanktonic organisms
						(*c*) In juveniles from 10 to 12 cm. predominantly small crustaceans like advanced zœa, *Acetes*, copepods and moderate amounts of phytoplanktonic organisms.

‡ Catch obtained in bag-nets.

TABLE I—(*Contd.*)

Species	Months of Occurrence	Size range and major group in brackets—Total length in cm.		Number of specimens examined		Food components
		1954	1955	1954	1955	
Family SCOMBEROMORIDÆ						
62. *Scomberomorus commerson* (Lacépède)	March and April	4–8 (6)	4–12 (6)	40	75	Exclusively small bony fish, mostly anchovies
63. *Scomberomorus guttatus* (Bloch and Schneider)	September	4–12 (6)	..	30	..	Young bony fishes
Family GOBIIDÆ						
64. *Glossogobius biocellatus* (Cuvier and Valencinnes)	March and April	3– 5 (4)	6– 7	21	1	Copepods and other crustaceans along with phytoplanktonic organisms
Family STROMATEIDÆ						
65. *Apolectus niger* (Bloch)	April		4– 6 (6)	..	4	Chiefly whitish pulpy matter with scales and bones as of lacerated young fish, also a few copepods, *Acetes* and other crustaceans
	June		4– 8 (7)	..	28	
	July†		5–10 (8)	..	123	
	July‡		9–14 (12)	..	65	
66. *Stromateus sinensis* (Euphrasen)	June		4– 7 (5)	..	4	Semidigested unrecognisable lacerated pulpy matter
Family PLATYCEPHALIDÆ						
67. *Platycephalus scaber* (Linnaeus)	March and April	7–8	6– 7	2	1	Chiefly stomatopod larvæ and other crustaceans

Family PESTTODIDÆ						
68. *Psettodes erumei* (Bloch and Schneider)	April	2–3	..	1	..	
Family BOTHIDÆ						
69. *Bothus pantherinus* (Ruppell)	March and April	3–9 (6)	6– 8 (6)	33	3	Amphipods and polychætes
Family PLOTOSIDÆ						
70. *Plotosus canius* Hamilton-Buchnan	March	..	9–10	..	4	Amphipods, isopods, mysids and young prawns
Family GADIDÆ						
71. *Bregmaceros maccelellandi* Thompson	December	4–5	..	4	..	Chiefly crustaceans, some with small egg capsules having yolk-laden eggs as of gastropods
Family TRIACANTHIDÆ						
72. *Triacanthus brevirostris* Schlegel	April	..	3– 4	..	2	Copepods and crustacean larvæ, with very little of phytoplanktonic organisms
Family TETRADONTIDÆ						
73. *Sphœrodon lunaris* (Bloch)	March and April	3–6 (3)	3– 6 (4)	75	21	Young fishes and crustaceans

† Catch obtained in boat-seines.
‡ Catch obtained in bag-nets.

The identification of a large number of very early juvenile stages, particularly in respect of closely related species where the distinguishing features have not been very clear, presented great difficulties and they were identified only up to the genus. Only when definite adult characters could be made out in the young forms, or when post-larval stages conformed to the descriptions given by earlier workers, they were identified up to the species. The classification adopted is after Berg (1940) and the nomenclature after Herre (1953) with slight modifications. Day (1889), Weber and Beaufort, Beaufort and Chapman (1911–51), Smith (1949), Munro (1955), Misra (1947) and Nair (1953) have also been consulted.

Relative numerical abundance of the juveniles of various species in different months.—In the months of March and April the families Siganidæ, Leiognathidæ, Carangidæ, Scombridæ, Lactariidæ and Dussumieridæ were best represented in the commercial catches, their numerical abundance ranging from about 6 to 30% of the total number of fish in the samples. The percentage composition of the juvenile fishes under different families occurring in March-April is given separately for the years 1954 and 1955 in Tables II and III.

TABLE II

Showing the percentage composition of the juvenile fishes under different families occurring in March-April 1954

	Name of family		Percentage composition
1.	Scombridæ	..	20·14
2.	Leiognathidæ	..	12·56
3.	Siganidæ	..	10·22
4.	Carangidæ	..	6·94
5.	Dussumieridæ	..	5·91
6.	Gerridæ	..	5·02
7.	Polynemidæ	..	3·74
8.	Sphyrænidæ	..	3·74
9.	Chirocentridæ	..	3·58
10.	Mullidæ	..	3·24
11.	Tetradontidæ	..	3·19
12.	Sciænidæ	..	2·98
13.	Clupeidæ	..	2·59
14.	Scombermoridæ	..	2·56
15.	Lactaridæ	..	2·21
16.	Lutianidæ	..	1·62
17.	Miscellaneous	..	8·80

TABLE III

Showing the percentage composition of the juvenile fishes under different families occurring in March-April 1955

	Name of family		Percentage composition
1.	Siganidæ	..	30·04
2.	Leiognathidæ	..	24·23
3.	Scombridæ	..	7·17
4.	Carangidæ	..	6·45
5.	Lactaridæ	..	5·37
6.	Polynemidæ	..	5·32
7.	Mullidæ	..	3·28
8.	Stromateidæ	..	3·23
9.	Clupeidæ	..	3·20
10.	Pomodasidæ	..	2·83
11.	Lutianidæ	..	2·64
12.	Chirocentridæ	..	1·12
13.	Miscellaneous	..	5·12

Besides the young stages of the bony fishes which were by far the commonest in the samples represented in Table I, there were in March-April a few Elasmobranchs, *viz.*, *Stegostoma varium*, *Scoliodon*, *sorrakowah*, *Narcine burnnea* and *Narke dipterygia* under the families, Orectolobidæ, Charcharinidæ and Torpedinidæ.

Size ranges and rate of growth of the juveniles.—The number of specimens, their size ranges and the major size groups in respect of all the species of the juvenile fishes obtained in the samples are given in Table I. Most of them, not exceeding a few centimetres in total length, could only be the recruits of the previous spawning season. In a few species like *Lactarius lactarius*, *Polynemus sextarius*, *Apolectus niger*, *Rastrelliger kanagurta*, which were represented in the samples collected over a period of several months, the average rate of growth has been studied by the size-frequency method.

It may thus be seen from Fig. 1 that *Lactarius lactarius* was represented in the month of March 1955 by individuals ranging in sizes from 3–6 cm. with the mode at 3 cm. In the months of April and June 1955 the modes were at 4–5 cm. respectively. It is therefore clear that the population has increased every month by an average size of 1 cm.

The frequency diagram (Fig. 2) for different months in respect of *Polynemus sextarius* show an increase in length of only 1 cm. during the period of April-July 1955. Although no appreciable growth is seen from month to month the maximum size for the species in different months indicates a definite increase in growth from 4–8 cm. during the period of April-June and from 8–10 cm. during June-July.

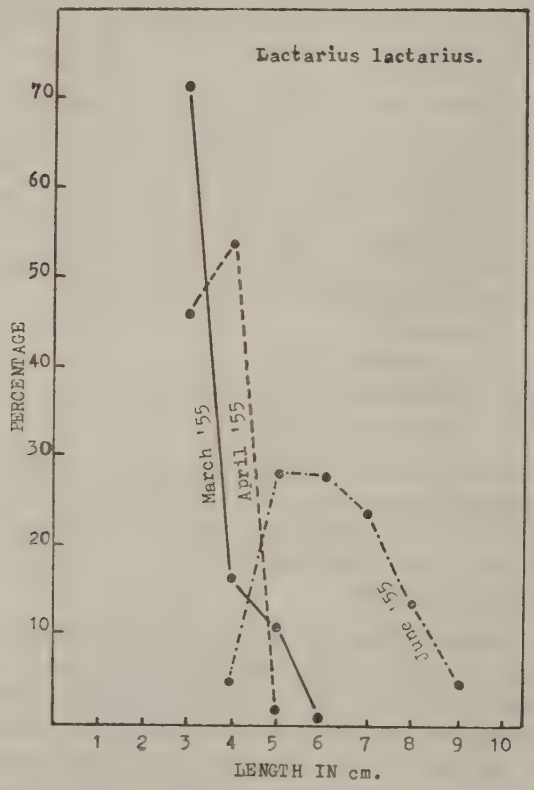

FIG. 1

In *Apolectus niger* a steady increase in length from April-July 1955 is evident from the size-frequency diagram (Fig. 3). In April 1955 the highest frequency size is 6 cm. In June there is a bimodal distribution of the individuals at 7 cm. and 9 cm. In the month of July the same bimodal distribution again occurs at 8 cm. and 12 cm. Apparently there are two distinct broods in the samples obtained in June and July 1955. The older brood of 9 cm.

length of June 1955 which is traceable to the 7 cm. size group of April 1955, seems to have attained a size of 12 cm. in July 1955; the younger brood 7 cm. length in June 1955 seems to have grown to 8 cm. in July 1955.

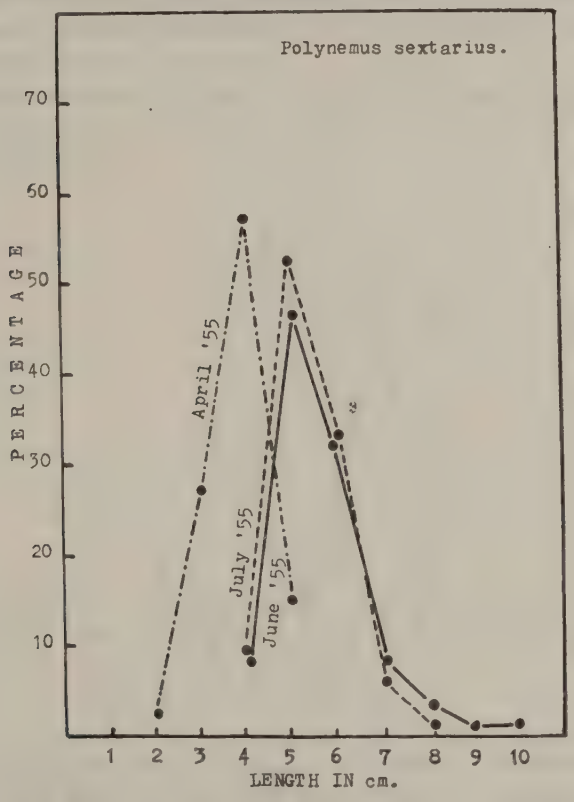

FIG. 2

The mode values of the *Rastrelliger kanagurta* (Fig. 4) may be read as 9 cm. in February, 8 cm. in March, 8 cm. in April, 13 cm. in June and 16 cm. in July. It is fairly clear from these length measurements that the highest frequency size groups of 9 cm. in February 1955 is represented by those at 13 cm. in June. The 8 cm. group occurring in March and April grows to 11 cm. in July. The recruitment to the smaller size groups continues in the months from February to April 1955. The majority size group of 16 cm. in July 1955 is not directly traceable to any of the size groups occurring in the earlier months. They probably represent members of a distinct brood older than the others belonging to the previous year.

Food and feeding habits of the juveniles.—Very little information is available on the food and feeding of the juvenile marine and estuarine fishes of India, the studies on the subject being chiefly confined to the observations of Bapat and Bal (1950 and 1952) on clupeoids and other groups of fishes, Gopinath (1942), Rao and Rao (1957) and Kuthalingam (1956).

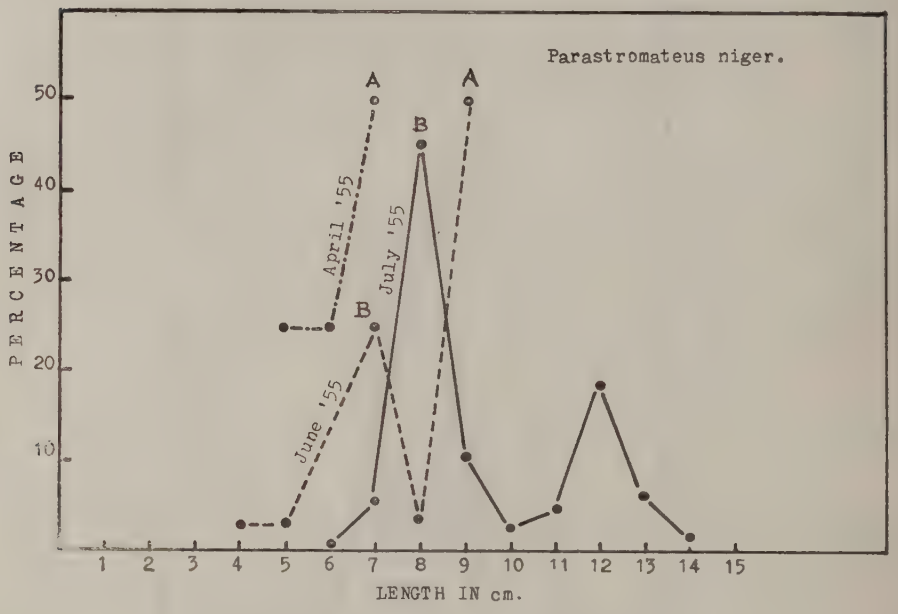

FIG. 3

In the present paper the stomach contents of 73 species of juvenile marine fishes belonging to 40 families have been studied with a view to observe the important components contributing to the food of the species. Observations have been made on material preserved in 5% formalin. Utmost care has been taken to see that any organisms present in the foregut are not mixed with the stomach contents, as the former are likely to be taken accidentally while the fish struggle in the net. Food components obtained from the stomachs were examined microscopically to determine the qualitative composition only. As the juvenile stages of the fish did not occur in the catches all through the year, no attempt was made to study the seasonal variation in their feeding habits. In very general terms it may be stated that no species of marine fish recorded in the list feeds exclusively on a herbivorous or purely phytoplankton diet. As is expected in their very early stages,

the fishes are mostly dependent on planktonic organisms. Some groups exhibit distinct carnivorous tendencies even in their very early stages. A few are very selective feeders on certain groups of zooplanktonic organisms and a few others appear to change their feeding habits with the growth in size. The items constituting the food are recorded against each species within the size ranges given in Table I.

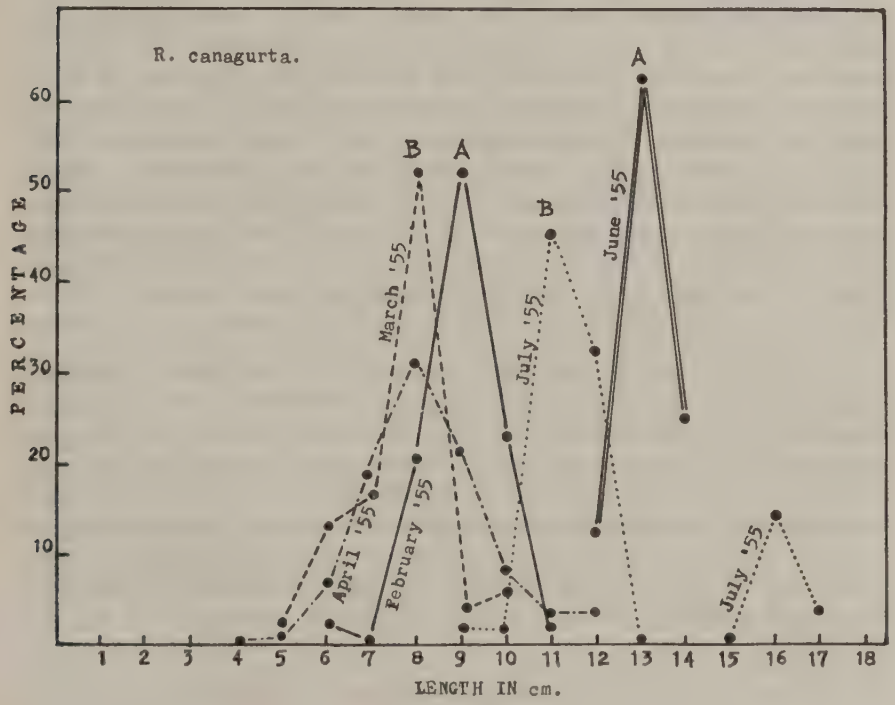

FIG. 4

Spawning periodicity.—The occurrence of young mackerel during March-April months of 1954 and 1955 confirms the observations of Rao and Basheeruddin (1953) that the species breeds during or after the north-east monsoon on the east coast. The appearance of large numbers of young individuals of various species,* besides mackerel, under the smaller size groups

* Subsequent to writing of this paper, one of us (S. B.) has noticed appreciable numbers of *Scomberomorus commerson* (Lacépède) with a size range of 20 to 80 mm. on 24th, 26th and 27th of February and on 3rd and 6th March 1960 in the shore-seine catches at Madras. This seems to be the first record of young *S. commerson* with a minimum size of 20 mm. occurring in the inshore waters of Madras.

shows that there is, in general, an intensive breeding activity in the months following the north-east monsoon which commences by about October and lasts till the middle of December. Panikkar and Aiyar (1939) have observed that the breeding of marine fishes is intense in December-January immediately succeeding the outbreak of the north-east monsoon. The juvenile individuals under large size groups of *Chirocentrus dorab* and *Trichiurus haumela*, judging from their size, are evidently not the result of breeding activity in or about the months in which the monsoon breaks. Some fish eggs and larvæ have been recorded from the coast in months other than those of north-east monsoon. Nair (1952) has recorded the post-larvæ of *Elops indicus*, perhaps a few weeks old from Madras in April. John (1951) has observed the larvæ of *Psettodes erumei* in July from this coast. Prabhu (1953) has observed that *Chirocentrus dorab* spawns in July-August. Bapat and Bal (1950 and 1952) have obtained several species of young fishes below 10 cm. in length during all seasons of the year. While the frequency distribution given in Table I is suggestive of an intensive breeding activity of most of the fishes during the months about north-east monsoon, a more detailed investigation is necessary to fix the period of spawning in each species.

Gopinath (1946) has recorded large number of post-larval fishes from November-April or even to May along the Trivandrum coast. Based on Sewell's (1949) observations that from November onwards a north-east monsoon drift sweeps up the coast of Ceylon and the west coast of India forming a strong coastal current in a northerly direction, Gopinath (1942) has presumed that the post-larval stages arrive from the spawning grounds situated elsewhere to the inshore waters of the west coast which seem to form a nursery. The observations reported here seem to indicate that there are important spawning grounds for these commercial species also in the Bay of Bengal.

Summary

The size frequency distribution and feeding habits of juvenile fishes occurring along the Madras coast from March 1954 to September 1955 are described. There seems to be a regular fluctuation in the appearance of juveniles of certain species.

While *Polynemus sextarius*, the younger brood of *Apolectus niger* and *Rastrelliger kanagurta*, showed a growth rate of 1–3 cm. respectively, *Lactarius lactarius* and the older brood of *Apolectus niger* exhibited the maximum growth rate of 3 cm. during the period of this study.

No species of marine fish recorded here feeds exclusively on a herbivorous or purely phytoplanktonic diet. A few species like *Rastrelliger kanagurta* appear to change their feeding habits with the increase in size.

The appearance of large numbers of young individuals of various species besides mackerel under the smaller size groups shows that there is in general an intensive breeding activity in the months following the north-east monsoon. This perhaps indicates that there are important spawning grounds in the Bay of Bengal.

Acknowledgement

The authors are thankful to Dr. N. K. Panikkar and Dr. S. Jones for their valuable criticism and for kindly going through the manuscript. The authors are indebted to Sri. K. Virabhadra Rao, the then Officer-in-Charge, Central Marine Fisheries Research Unit, Madras, without whose continued interest throughout the period of this study, this paper would have been impossible.

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ON FISHES OF THE SUBFAMILY SCOMBEROMORINÆ (FAMILY SCOMBRIDÆ) FROM INDIAN WATERS

By S. Jones and E. G. Silas

(Central Marine Fisheries Research Institute)

Introduction

While hardly a dozen species of spanish mackerels or seerfishes are recognisable at present from the warmer waters of the Indo-Pacific and the Atlantic, only recently has the nomenclature used to denote these, attained any degree of stability. Though some workers may be still inclined to treat *Scomberomorus* Lacépède, and *Acanthocybium* Gill, under two separate families or subfamilies, for reasons given elsewhere (Jones and Silas, 1960, 376), it is felt that for all practical purposes it will be desirable to treat these as two distinct genera under the subfamily Scomberomorinæ of the family Scombridæ.

In the course of the present study we have encountered only three species of spanish mackerels from the Indian coast. Although this number may be considered to be too few, we have often found field-workers unable to correctly identify them when confronted with them in the fresh state in the fish-landing centres. Since the spanish mackerels constitute an important coastal pelagic fishery along most parts of the Indian coast, and as often two or all three species are landed with the same type of gear or different types of gear at the same place, it is imperative that stress be also laid on accuracy in species determination. It is hoped that this brief review will help fishery workers in their study on this group of fishes.*

The methodology used for body proportions, and collection of other data, does not deviate from that given for 'Indian Tunas' (Jones and Silas, 1960, p. 372).

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* In spite of the spanish mackerels forming important fishery along many parts of our coast, the only information available on the biology of these species by Indian workers is limited to the contributions of Krishnamoorthi (1957, *Indian J. Fish.*, **4**, 229–53; 1958, *Ibid.*, **5**, 270–81), and Jones (1961, *Indian J. Fish.*, **8**, 107–20). Vijayaraghavan (1955, *Indian J. Fish.*, **2**, 360–72), and Kuthalingam [1959, *J. Madras Univ.*, **29** (2), 139–50] have described the early stages and food and feeding habits of *S. guttatus* and *S. lineolatus* respectively but according to Jones (1961, *loc. cit.*) these do not appear to relate to any species of *Scomberomorus* Lacépède.

RÉSUMÉ

A brief résumé of recent work on scomberomorinae taxonomy is necessary for a proper understanding of the nomenclature used in this study. Day (1878) used the generic name *Cybium* Cuvier to denote five species from Indian seas which are at present referable to *Scomberomorus* Lacépède, the latter name as clearly shown by Munro (1943) having priority over the former. Besides, *Cybium* as used by Day was a composite genus which included as synonyms *Acanthocybium* Gill (a distinct genus of Scomberomorinæ), and *Lepidocybium* Gill (a genus of the family Gempylidæ). The five species of *Cybium* which Day recognised from Indian seas are referable to only three species, *S. guttatus*, *S. lineolatus* and *S. commerson* as shown below:—

Species as given by Day (1878)	Up-to-date nomenclature
1. *Cybium kuhlii* Cuvier and Valenciennes	= *Scomberomorus guttatus* (Bloch and Schneider)
2. *Cybium interruptum* Cuvier and Valenciennes	= *Scomberomorus lineolatus* (Cuvier)
3. *Cybium guttatum* (Bloch and Schneider)	= *Scomberomorus guttatus* (Bloch and Schneider)
4. *Cybium commersonii* (Lacépède)	= *Scomberomorus commerson* (Lacépède)
5. *Cybium lineolatum* Cuvier and Valenciennes	= *Scomberomorus lineolatus* (Cuvier)

Kishinouye (1923) used the generic name *Cybium* Cuvier and also included in his comparative study of scombroid fishes, *C. commerson*, and *C. guttatum*. Munro's (1943) critical work on the Australian species of *Scomberomorus* has contributed greatly towards our proper understanding of the nomenclatorial status of some of the Indo-Pacific species. His subdivision of the genus into nine subgenera, *Scomberomorus* Jordan and Hubbs; *Cybium* Jordan and Hubbs; *Sawara* Jordan and Hubbs; *Pseudosawara* Munro; *Indocybium* Munro; *Sierra* Fowler; *Chriometra* Lockington; *Cybiosarda* Whitley; and *Lepidocybium* Gill, may not find universal approval. As he pointed out at the time, and subsequently has clearly shown (Munro, 1949), *Lepidocybium* is a gempylid. We have elsewhere placed *Cybiosarda* under the subfamily *Thunninæ* (Jones and Silas, 1960). De Beaufort (1951) has already shown that as the type of *Pseudosawara*, namely, *Cybium kuhlii*

is a synonym of *Scomber guttatum* [= *Scomberomorus* (*Indocybium*) *guttatus*] *Pseudosawara* becomes a synonym of *Indocybium* Munro. The species pertaining to the five remaining subgenera as proposed by Munro (1943) have been placed under two subgenera, *Scomberomorus* s. str., and *Cybium*, by Fraser-Brunner (1950), the primary distinction being that in the species of the typical subgenus the air-bladder is absent, while it is present in the two species of *Cybium*. Munro (1943) has shown that the presence or absence of air-bladder in the genus *Scomberomorus* cannot be considered to be of much taxonomic significance as it may or may not be present in the same species in different locations along its range of distribution (*e.g.*, *S. commerson*). Besides, we are not quite in full agreement with Fraser-Brunner's treatment of the species from the Indo-Pacific, as will be seen from the arrangement of the species in this account.* Recently Munro (1955) has used *Cybium* and *Indocybium* as distinct genera, which we had also followed elsewhere (Jones and Silas, 1960, p. 377). Reconsidering the matter we feel that while infrageneric categories of *Scomberomorus* may be admissible, the excessive splitting of the subfamily into genera is not desirable, for, a careful scrutiny of the works of Fraser-Brunner (1950), and the regional works on scomberomoroid fishes by Munro (1943), Smith (1949), de Beaufort (1951), Deraniyagala (1953), and Williams (1960) show that the differences between the Atlantic and the Indo-Pacific seerfishes or spanish mackerels are not so great as one would be led to consider at first. Almost every species in the Atlantic has its close counterpart in the Indo-Pacific and as in the Tunas, there is an urgent need for a critical study of the species of spanish mackerels on a global basis. Until such time we feel that the use of the generic name *Scomberomorus* to include the three Indian species of spanish mackerel will serve the purpose.

Based on osteological and morphological characters Kishinouye (1923), and Conrad (1938) have drawn attention to the specialised features of *Acanthocybium*, but at the same time shown its closer affinities to *Scomberomorus* (or *Cybium*) than to any other group of scombroid fishes.

Key to the Identification of the Genera and Species of Indian Scomberomorinae

1 *a*. First dorsal with XIV to XVII spines; gill rakers present; gill lamellæ not reticulated; lateral line slightly undulate or with a deep inflection behind second dorsal (*Scomberomorus* Lacépède) 2

* Subsequently in a personal communication Mr. Fraser-Brunner has clarified some of the points concerning his aforesaid work such as: substitution of the word 'two' instead of 'all' in line 9 from bottom on p. 136; "*Cybium lineolatum*" to be separated from the synonymy of *S. (S) guttatus* (p. 160) since it is a distinct species.

1 *b*. First dorsal with XXIII to XXVII spines; gill rakers absent; gill lamellæ reticulated; lateral line with a deep inflection beneath X to XV first dorsal spines (*Acanthocybium* Gill).
.....*Acanthocybium solandri* (Cuvier)

2 *a*. Gill rakers 2 to 6 (generally 3 or 4) on lower limb of outer arch; a deep inflection in the lateral line below posterior end of D_2 to second dorsal finlet behind it; sides of body of juveniles with large black blotches merging to form distinct dark vertical irregular stripes in adult..... *Scomberomorus commerson* (Lacépède)

2 *b*. Gill rakers 7 to 11 on lower limb of outer arch; lateral line running as an even curve above gill opening and pectoral to below second dorsal behind which it may slightly undulate; sides of body with small rounded black spots or with horizontally elongate black streaks 3

3 *a*. Sides of body with roundish black spots more prominent beneath and just behind pectorals; caudal keel narrow. Distance from D_2 to caudal fork distinctly longer than second predorsal length.
.....*Scomberomorus guttatus* (Bloch and Schneider)

3 *b*. Sides of body with irregular rows of horizontal black streaks or broken bars; caudal keel conspicuously broad. Distance from D_2 to caudal fork usually shorter than or rarely equal to the second predorsal length.....*Scomberomorus lineolatus* (Cuvier)

Acanthocybium solandri (Cuvier)

(Figs. 1; 5 *a*; 6 *a*; and 7 *a*)

Cybium solandri Cuvier, 1831. *Hist. Nat. Poiss.*, **8**, 192–93 (Type locality: unknown).

SYNONYMY.—Reference may be made to de Beaufort (1951), Deraniyagala (1952) and Rao (1960).

POPULAR NAME.—Wahoo.

REMARKS.—Good descriptions of *A. solandri* from this region already exist in the references cited under 'Synonymy'. These indicate the meristic count in this species to be:

D_1. XXIII–XXVII; D_2. III, 9–10 + 8–10; A. III, 9 10 + 7–9; P_1. ii, 21; P_2. i, 5. Vertebræ 23–33 + 31–34 = 54–66. For four specimens from Vizhingam, Rao (*op. cit.*) found the counts to be 62 (2); 63 (1) and 64 (1).

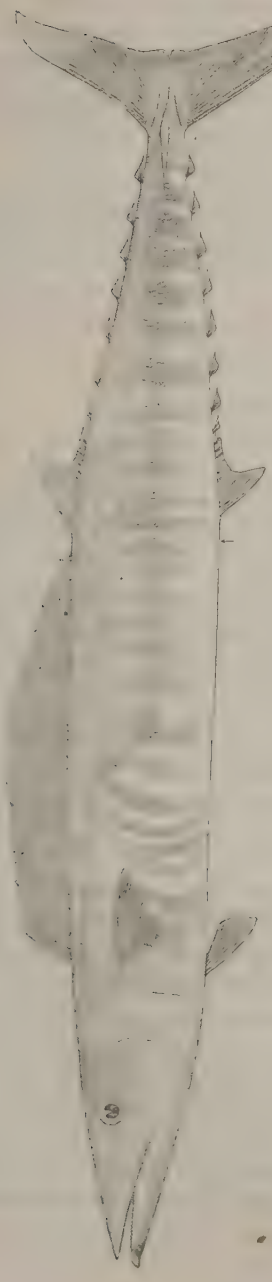

FIG. 1. *Acanthocybium solandri* (Cuvier). Specimen 812 mm. from Andamans.

FIG. 2. *Scomberomorus commerson* (Lacépède). Specimen 810 mm. from Andamans.

Herre (1953) resurrected the name *A. forbeei* Seale (1912) from the synonymy of *A. solandri*, but we do not see any grounds for specific separation. *Cybium sara* Lay and Bennet (1839) is yet another synonymy of *A. solandri*.

The wahoo, known the world over as one of the best marine game fishes, attains a length of well over two metres and a weight of 45 kg. or more.

Occurrence in Indian Waters.—On the west coast from Vizhingam, Colachel and Cape Comorin; on the east coast from Tuticorin, Gulf of Mannar; Minicoy Island in the Laccadive Archipelago; and Port Blair, Andamans.

General Distribution.—Warmer waters of the Atlantic, Pacific and Indian Oceans and the Mediterranean.

Scomberomorus commerson (Lecépède)

(Figs. 2; 5 *b*; 6 *b*; and 7 *b*)

Scomber commerson Lacépède, 1800. *Hist. Nat. Poiss.*, **2**, 598–603, pl. 20, Fig. 1 (based on MS Drawing by Commerson. Type locality: Mauritius as given by Cuvier).

Synonymy.—*Scomber maculosus* Shaw (1807) (Based on 'Konam' of Russell, 1803, p. 27, pl. CXXXV). *Cybium konam* Bleeker (1851) and *Scomberomorus konam* Bleeker (1851). *Cybium multifasciatum* Kishinouye (1915).

The specific name *commerson* has been used as *commersoni* and *commersonii* by earlier workers. For detailed synonymy reference may be made to Munro (1943), and de Beaufort (1951).

Popular Names.—Seerfish or Barred spanish mackerel.

Remarks.—Growth stage of *S. commerson* shows considerable difference in body colouration, but the patterns are more or less constant in the different stages. The meristic characters for this species generally falls within the range given by Munro (1943), namely D_1. XIV–XVII; D_2. 16–19 + 8–10; A. 14–18 + 8–10; Gill rakers 0–2 + 3–6; Vertebræ 20 + 25 = 45.

In addition we have encountered specimens showing gill-raker counts of: 2 + 2; 2 + 5; 2 + 6; and 1 + 5, but for the Indian specimens 2 + 3 or 4 is the most frequent combination seen.

As in *Acanthocybium solandri*, large examples of *S. commerson* show short lateral branchings of the lateral line, a feature already commented on by Munro (1943) and Deraniyagala (1952).

Occurrence in Indian Waters.—From all along the Indian coast and Andamans. In the Laccadive Archipelago, Minicoy Islanders use the name 'Digumas' (other than *Acanthocybium* which is also known by this name) to denote a species of *Scomberomorus* which in all probability refers to *S. commerson*, but this needs confirmation.

General Distribution.—*S. commerson* is the most widely distributed species of the genus. It is known from the Red Sea, East Coast of Africa as far south as Cape of Good Hope, and eastwards through Mauritius, and the coasts of India, Ceylon, Burma, Malaya to the Australian coast, Philippines, Formosa and Japan.

Scomberomorus guttatus (Bloch and Schneider)

(Figs. 3; 5 *d*; 6 *c*, *d*; and 7 *c*, *d*)

Scomber guttatus Bloch and Schneider, 1801. *Syst. Ichthyol.*, **23** (Type locality: Tranquebar, India).

Synonymy.—*Scomber leopardus* Shaw (1803), *Cybium kuhli* Cuvier and Valenciennes (1831). For detailed synonymy reference may be made to de Beaufort (1951). In addition, *Scomber leopardus* Shaw (1803) based on Russell's drawing and characterisation of a fish he called by the local name *Wingeram* (first species under his division Scomber) is a definite synonym of *S. guttatus*. However, Smith (1949) and Fourmanoir (1957) have used the name *Scomberomorus leopardus* erroneously for the species *S. lineolatus* as has been also drawn attention to by Williams (1960). Besides *S. leopardus* (Shaw), Fraser-Brunner (1950) included with a query under *S. guttatus* both *Cybium lineolatum* and *interruptum* as synonyms, but *S. lineolatus* (Cuvier) of which *C. interruptum* is a synonym (*see* Williams, 1960) is a distinct species.

Popular Name.—Spotted spanish mackerel.

Remarks.—The original diagnosis of *Cybium kuhli* Cuvier is very brief, but de Beaufort (1951) has given reasons for considering it a synonym of *S. guttatus*. Further de Beaufort mentions that "Day's species, however, cannot be *kuhli* C.V. (= *guttatum* C.V.) if at least the number of pectoral rays, which Day gives as 29, is a misprint". No species of *Scomberomorus* has such a high pectoral finray count which for the genus varies from 15 to 23. Day's drawing of *C. kuhlii* (pl. lvi, fig. 2) shows 16 rays and hence there can be no doubt that the number 29 is a misprint. The colour of *C. kuhlii* is given by Day as "....bluish above becoming silvery on the side and below. After death the sides assume a dark hue and have

FIG. 3. *Scomberomorus guttatus* (Bloch and Schneider). Specimen 533 mm. from Tuticorin, Gulf of Mannar.

FIG. 4. *Scomberomorus lineolatus* (Cuvier). Specimen 680 mm. from Tuticorin, Gulf of Mannar.

neither bands nor spots: first dorsal black; second dorsal and also anal with dark bases; pectoral with a light outer edge, tips of caudal dark". We have on rare occasions seen freshly caught specimens of *S. guttatus* in which the sides of the body lack the usual spots, being silvery tinged with grey on the upper half of the body, but not differing in the least in other diagnostic characters. This may be one extreme in adult body colouration in this species, while at the other extreme is the condition wherein the sides of the body is studded with innumerable small roundish black spots, about eight irregular rows discernible just behind the pectoral while normally only three or four rows of such spots are seen along the sides of the body.

Of the three species of *Scomberomorus* occurring along our coast, the lateral line is least undulating in its posterior length in *S. guttatus*. In the specimens examined the meristic counts vary as follows:—

D_1. XVI–XVII; D_2. 20–21 + 7–9; P_1. 21–23; A. 19 20 + 7–9; Gill rakers 1–3 + 7–10. The most frequent counts are D_1. XVI; D_2. finlets 8: P_1. 21; A. finlets 8; Gill rakers 2 + 8–9.

Munro (1943) gives the vertebral count of this species as 20 + 26 = 46, and Delsman (1931) as 45–46 (*S. guttatus* 20 + 26 = 46; *S. kuhlii* 20 + 25 = 45). The specimens we have examined from the Tuticorin and Vizhingam coasts show a total number of 48 or 49 vertebræ. Kishinouye (1923) mentions 51 as the count for *Cybium guttatum* from Formosan waters. Thus it would appear that of the three Indian species of *Scomberomorus*, the range of variation of vertebral counts is greatest in *S. guttatus*. The significance of this is not apparent as the stray observations hitherto made do not lead to any conclusions except draw attention to the likelihood of there being geographical races or distinct populations in different geographical locations along the range of distribution of this species.

Several records of *S. guttatus* from Australian waters are referable either to *S. semifasciatus* (Macleay) or *S. queenslandicus* Munro. The absence of records of this species from the British East African coast is interesting.

Occurrence in Indian Waters.—All along the Indian coast and the Andaman Islands.

General Distribution.—Iranian Gulf, Madagascar and Sonth East Africa, Coast of India, Ceylon, Burma, Malaya, Indonesia, Philippines, China and Formosa.

Scomberomorus lineolatus (Cuvier)

(Figs. 4; 5 *c*; 6 *d*; and 7 *e*)

Cybium lineolatum Cuvier, 1831. *Hist. Nat. Poiss.*, **8**, 170 (Type locality: Malabar).

SYNONYMY.—Reference may be made to de Beaufort (1951) and Williams (1960).

POPULAR NAME.—Streaked spanish mackerel.

REMARKS.—A very distinct species of which a critical taxonomic study has been recently carried out by Williams (1960). His study confirms the conspecificity of *S. lineolatus* and *S. interruptum* (Cuvier), as was considered by Smith (1949) and de Beaufort (1951). As mentioned earlier, the nominal species *S. leopardus* Shaw, counfounded with *S. lineolatus* by some workers, is a synonym of *S. guttatus*.

For specimens we have examined from the Indian coast the meristic counts vary as follows:—

D_1. XVI–XVII; D_2. 19–20 + 8–9; A. 18–20 + 8–11; Gill rakers 2–3 + 8–11.

Delsman (1931) and Munro (1943) give the vertebral count of *S. lineolatus* as 21 + 29 = 50. In two specimens we have examined from Tuticorin the total count is 49.

Besides the characteristic colouration of blackish narrow streaks or broken bars on the sides of the body, two other conspicuous features seen in juveniles as well as adults are: the markedly rounded ridge running from the side of the pointed snout to the end of the operculum in line with the base of the pectoral fin (Fig. 5 *c*), and the conspicuous laterally expanded caudal keels (Fig. 7 *e*).

OCCURRENCE IN INDIAN WATERS.—All along the Indian coast, but generally rarer than the two preceding species.

GENERAL DISTRIBUTION.—British East African waters; Natal coast of South Africa; ? Mozambique Channel and Madagascar; Ceylon, India to the East Indies (Williams, 1960).

SOME COMPARISONS

Text-figures 5–7 are given here mainly to focus attention on additional differences between the species dealt with here. From Fig. 5 it will be seen that the snout in *A. solandri* is conspicuously long and pointed, which condition to a lesser degree is seen in *S. commerson*, and *S. lineolatus*, while in *S. guttatus* the snout is markedly short. Besides in the last-said species, the dorsal profile of the head shows a distinct upward curve slightly ahead of the anterior nostril. The teeth on the jaws are more numerous in *A. solandri*, being 40–55 on each side of the upper and lower jaws while about

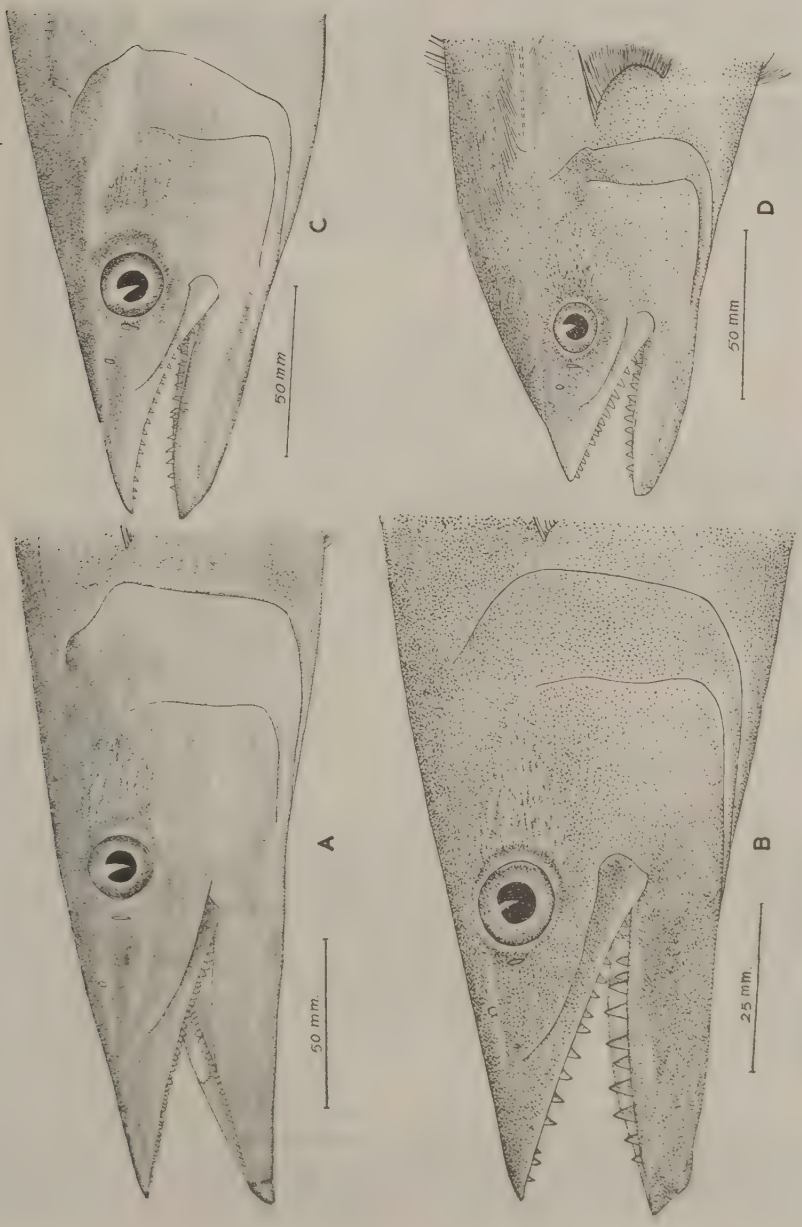

FIG. 5. Lateral view of the head of: (A) *Acanthocybium solandri* (Cuvier); (B) *Scomberomorus commerson* (Lacépède); (C) *S. guttatus* (Bloch and Schneider); and (D) *S. lineolatus* (Cuvier).

12–25 are seen in the species of *Scomberomorus*. In addition, the teeth in *A. solandri* are closely arranged in the jaws, progressively increasing in size posteriorly. They are also broadly triangular with minutely serrated edges. In the species of *Scomberomorus* the teeth are more widely spaced; the series on the lower jaw slightly larger than those on the upper jaw; all teeth slightly directed inwards; and the few middle teeth of each side of the lower jaw larger than the rest in the series, this condition being well seen in *S. commerson*, which has also the outer edges of its teeth finely serrated. The premaxilla is least exposed below the lachrymal in adult *S. lineolatus*.

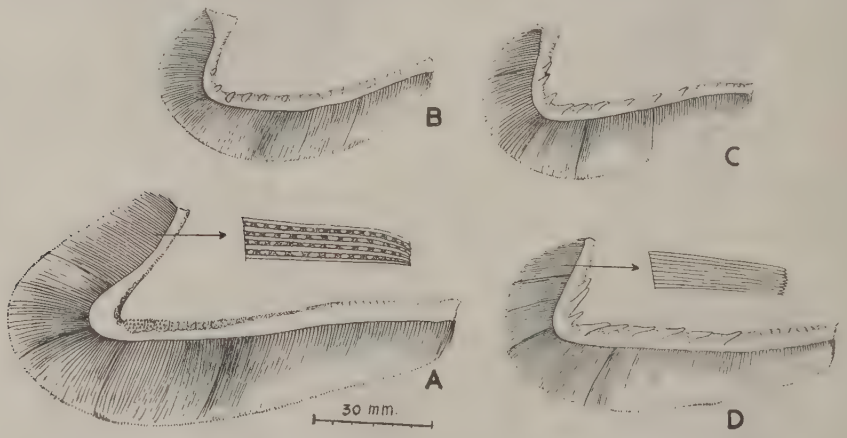

FIG. 6. Outermost gill arch of the right side of: (A) *Acanthocybium solandri* (Cuvier); (B) *Scomberomorus commerson* (Lacépède)—juvenile; (C) *S. guttatus* (Bloch and Schneider); and (D) *S. lineolatus* (Cuvier and Valenciennes).

The outer gill arch of each species figured (Fig. 6) shows the total absence of gill rakers in *A. solandri*; the reduced number of rakers in *S. commerson*; the relatively stumpy gill rakers of *S. guttatus*; and the more developed condition in *S. lineolatus*. These variations can probably be correlated with the food habits and the sizes and disposition of the teeth in the jaws of these species. A unique feature in *A. solandri* is the reticulated nature of the gill filaments (Fig. 6 *A*), which is quite different from the normal arrangement of the gill filaments as shown here for *S. lineolatus* (Fig. 6 *D*).

The species are characterised by a pair of lateral peduncular keels and two pairs of caudal keels, one at the upper and the other at the lower half of the base of the caudal fin (Fig. 7). The peduncular keels are long and narrow and end at the middle of the base of the caudal fin in *A. solandri*.

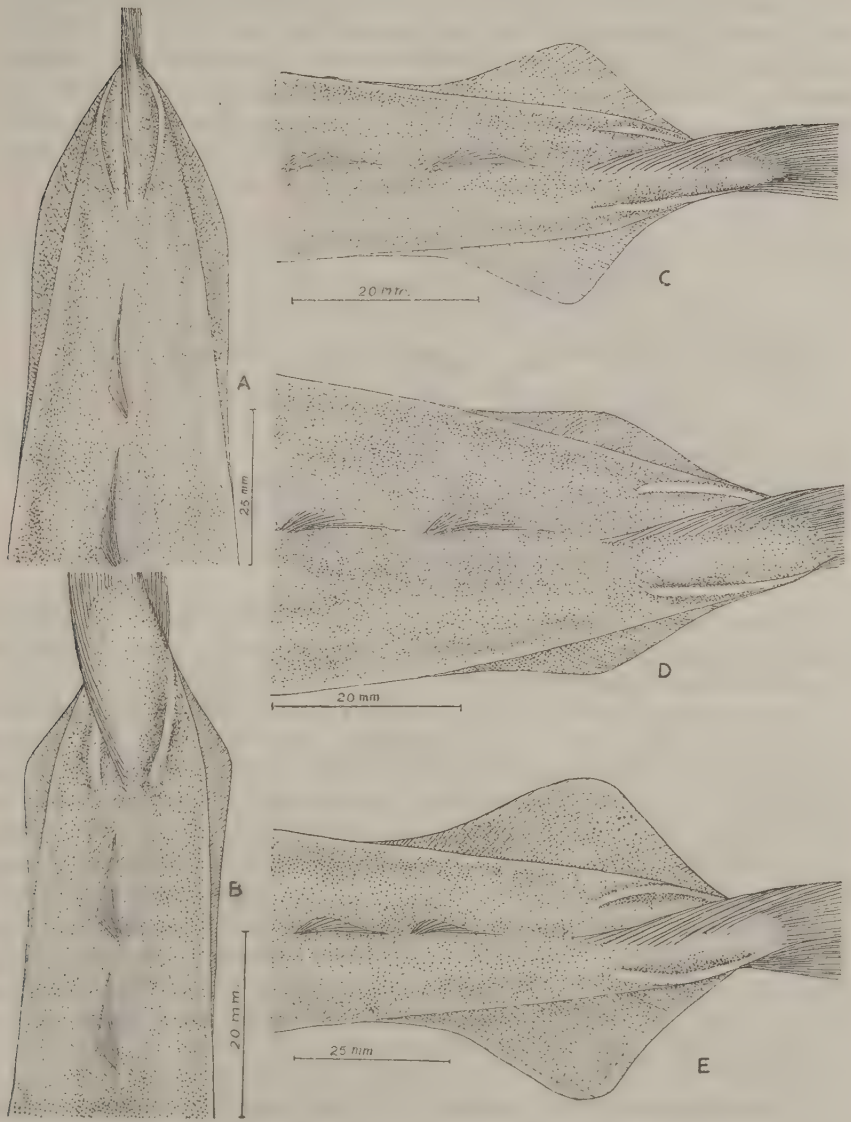

FIG. 7. Dorsal view of caudal peduncle showing nature of caudal peduncular keels in: (A) *Acanthocybium solandri* (Cuvier); (B) *Scomberomorus commerson* (Lacépède)—adult; (C) *S. guttatus* (Bloch and Schneider)—juvenile; (D) Same—adult; (E) *S. lineolatus* (Cuvier) —adult.

In *S. commerson*, the condition is more or less the same, but the keel ends well in front of the base of the caudal fin as in other species of *Scomberomorus*. The peduncular keels are most prominent in *S. lineolatus* where the width at its widest part will be about one-fourth its basal length. In adult specimens of *A. solandri*, *S. commerson*, and *S. guttatus* the greatest width of the caudal keel on one side is contained 5·5 times or more in the basal length of the keel.

FIG. 8. *Scomberomorus queenslandicus* Munro (after Munro, 1943).

GENERAL REMARKS

Certain species of *Scomberomorus* have restricted distribution, but it is likely that one or two may turn up as rarities in Indian waters. From the pattern of distribution of the species, the one most likely to occur may be *S. queenslandicus* Munro (Fig. 8), a species closely allied to *S. commerson* but showing the following characteristics: D_1. XV–XVII; D_2. 16–20 + 9–10; P_1. 20–23; A. 15–20 + 9–10; gill rakers 0-1 + 4–7; and vertebræ 20 + 28 = 48. Unlike the vertical bars seen in the adults of *S. commerson*, in *S. queenslandicus* the sides of the body are marked with diffuse rounded blotches, each larger than the diameter of the eye and arranged in about three rows below the lateral line. Another notable difference is the absence of a deep inflection in the lateral line in *S. queenslandicus*. This species is at present known from both the east and west coasts of Australia, and on account of its colouration has often been confused by Australian workers with *S. guttatus*. Specimens of this species from Indian waters should be preserved.

Another species which has most often figured in scomberomorid taxonomy is the rare gempylid *Lepidocybium flavobrunneum* (Smith) (Fig. 9) related to *Gempylus serpens* Cuvier recently recorded for the first time from this part of the Indian Ocean (Jones, 1960). No doubt, the general shape of the body, the presence of a spinous dorsal, and dorsal and anal finlets and

the wide peduncular keels give it the scombroid appearance, but careful examination will show the differences in the (1) fewer number of dorsal spines (VIII–XI); (2) fewer dorsal and anal finlets (4–6 dorsal and 4–5 anal finlets); (3) teeth conical and recurved; (4) gill rakers undeveloped or in the form of 6 or 7 vestigeal projections on the lower limb of the outer gill arch; (5) the skeletal character, namely the caudal rays not deeply forked at the base and consequently the hypural mostly exposed. The tortuous lateral line which may always not be well defined is another specific character. Any worker who happens to come across this rarity from the Indian seas should not fail to preserve the specimen and in order to facilitate in its identification a figure of it is also given here.

FIG. 9. *Lepidocybium flavobrunneum* (Smith). Drawn from a photograph of a specimen from Hawaiian waters, kindly sent by Mr. J. C. Marr, Director, Pacific Oceanic Fisheries Investigations, Honolulu, Hawaii.

The relative sizes attained by the species of Indian spanish mackerels vary. *S. commerson* attains the largest size and specimens 1·2–1·3 metres long taken in line fishing or in shore seines weigh 12–15 kg. Such large specimens were invariably found to be females, but a large male 99 cm. with fully mature testes weighed 7·7 kg. We have no information whether males and females of such large size occur together during spawning season or whether the males are smaller or belong to a different year class than the females. One instance worth mentioning is that of seven *S. commerson* taken on troll lines used from the ferry steamer S.S. CHOLUNGA in February 1960 in the Port Blair—Mayabunder run in the Andamans, three males, all oozing milt measured 750, 780 and 810 mm. while the four females taken in the same vicinity measured 1100-1200 mm. and had ovaries almost fully ripe. Generally specimens between 180 and 500 mm. are taken in gill nets along most parts of our coast, while it is not uncommon to see specimens ranging from small size to 1 metre or over taken in a single shore seine haul when more than one school is caught. Munro (1943) notes that besides the

regular fishery of small-sized specimens weighing about 5·5 kg., occasionally 22–27 kg. specimens of *S. commerson* are taken in the North Queensland and Western Australian waters, specimens 140 cm. weighing 18–23 kg. Rare exceptions of 40–45 kg. weights for *S. commerson* measuring about 2 metres in length are known. However, the record size appears to the one mentioned by Ogilby and Marshall (1954) of a specimen 7 feet 6 inches (2·286 metres) weighing 58·96 kg. taken off Townsville, Australia in 1948.

S. lineolatus comes next in the order of size. We have examined several specimens caught in shore seines and drift nets along parts of Madras and Kerala coasts measuring between 600 and 800 mm. and weighing from 3·6–5·5 kg. Smaller specimens are usually taken in gill nets and shore seines. In no case were the gonads mature, which suggests that the species may attain a still larger size. Willaims (1960) gives 3–3·6 kg. as the average weight of *S. lineolatus* taken along the British East African Coast and mentions that spent females are obtained in September-November months. Hardly any information is available about the ecology and biology of this species from the Indian seas.

Specimens of *S. guttatus* between 450 and 520 mm. in length and weighing between 0·5–1·5 kg. taken along parts of the Madras coast are found to have fully mature gonads during the months May–July. In several places along our coast numerically this species is landed more than either *S. commerson* or *S. lineolatus*. Krishnamoorthi's work (1958) on the biology of this species from the Rameswaram Island (Madras coast) indicates that it may attain 885 mm. and we have seen one caught in November at Rameswaram measuring 815 mm. Krishnamoorthi, however, does not report the occurrence of *S. lineolatus* at Rameswaram Island, though we find it regularly occurring in the catches along with *S. guttatus* and *S. commerson*, though not in such large numbers as *S. guttatus*.

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SOME OBSERVATIONS ON THE SHOALING BEHAVIOUR OF THE OIL-SARDINE *SARDINELLA LONGICEPS* VAL.

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Introduction

The importance of the knowledge of the behaviour of fish in their natural environment which enables their easier location, the devising of better gear and techniques of capture has long been realized by fishery workers. Studies of that nature already conducted have proved to be of considerable interest and value in the case of various fishes such as the Australian pilchard *Sardinops neopilchardus* (Blackburn, 1941; Blackburn and Tubb, 1950), the California sardine, *Sardinops cærulea* (Anon, 1952), the Japanese sardine, *Sardinops melanosticta* (Nomura, 1958), the " lemuru ", *Sardinella allecia* (Soerjodinoto, 1958), the Atlantic salmon (Keenleyside, 1958), the tunas, *Katsuwonus pelamis* (Strasburg and Yuen, 1958), *Neothunnus macropterus* and *Euthynnus yaito* (Tester *et al.*, 1955), the lajang, *Decapterus* spp. (Soemarto, 1958), the cichlid, *Tilapia esculenta*, the cat fish, *Clarias* (Beauchamp, 1958), and the minnow, *Phoxinus phoxinus* (Jones, 1958). Kesteven (1960) in an exhaustive review has lucidly dealt with almost all aspects of behaviour of fishes. No attempts have hitherto been made towards studies on the shoaling behaviour of fishes of Indian waters. In view of the importance of the fishery of oil-sardine *Sardinella longiceps* on the south-west coast of India, it was thought desirable to investigate the shoaling behaviour of this species.

Various definitions have been given for the term shoal or school by different authors. According to Blackburn and Tubb (1950) " A fish school is a dense concentration of fish very close to or actually breaking the surface of the sea, in such a way that the observer sees a circumscribed and, at any given moment, a fairly well-delimited area whitened with foam, or coloured by the fish themselves or both. " Keenleyside (1955) as quoted by Kesteven (1960) defined it as "an aggregate formed when one fish reacts to one or more other fish by staying near them (the chief factor common to all schools is a definite mutual attraction between individuals)". Tinbergen (1951) and Brown (1957) are in agreement with this definition. The latter further advanced the view that " the individuals within a school have an individual body odour

recognizable by each member of the school". The definition given by Messyazev* (1937) as quoted by Zusser (1958) is as follows: "A fish school is a biological category limited by the species—number and length composition of fishes. Further, fish aggregation is a local concentration of several separate schools and is composed of fishes of one or more species and of different sizes. Consequently, an aggregation is, generally, a temporary formation, heterogeneous and unstable in regard to its specific and size composition."

The term behaviour was used in the broadest sense by many authors to cover all the actions of an animal. Thus, according to Tinbergen (*loc. cit.*) behaviour is "the total of movements made by the intact animal". Kesteven (*loc. cit.*, p. 8) stated, "In a physiological approach to behaviour, analysis is made in terms of receptors and affectors, stimulus intensity and responses; in the ethological approach analysis is made in terms of internal drive or motivation, releasing mechanisms, sign stimuli, and an hierarchy of behaviour patterns." In the present investigation, the term shoal is used to mean a dense or loose concentration of fish at the surface or sub-surface of the sea and also recognized by the presence of a faint colour caused by the fish themselves during the day, or by their luminescence during nights, with or without a definite shape, visible to the eye. he various actions of the fish, individual and collective, in the shoal, under natural conditions, are brought under the term shoaling behaviour here.

Material and Methods

Routine scouting trips were made from October 1957 to November 1958 in the inshore area off Calicut with the aid of a canoe about 8 metres in length. These operations were confined mostly to the 3·5–15·0 metre area (on one occasion such a trip extended up to 22·0 metre area also), covering a distance of about six miles, north to south. As soon as a sardine shoal was encountered, its direction of movement, shape, length, breadth and its other characteristic features were noted; then sardine samples were taken with the aid of a stringed cast net *Veechu Vala* to determine their size composition. Immediately after casting the net, the surface sea-temperature was noted. The direction of water flow was determined with the aid of a wooden float; the float was put in the sea and its direction of movement with reference to shore (while the boat was kept anchored) was noted. The current direction was also checked up by anchoring the boat and watching its position in relation to the flow of water. Simultaneously, turbidity of the sea was noted with the aid of a Secchi disc (measuring 20·0 cm. in diameter); the depth

* Reference not seen.

at which the disc was just visible and the depth at which it disappeared from view were noted and the average value was taken as the turbidity (or transparency) figure. The direction of the wind was noted down by rough observations. The presence of predators, when any, was also taken note of.

Shoaling Behaviour

(*A*) *Surface Shoals*

The characteristic features of different kinds of shoals encountered are described below. The terms flipping (Blackburn and Tubb, 1950) and pattering (Blackburn, 1941 and Blackburn and Tubb, 1950) were applied to particular types of behaviour of the shoals of *Sardinops neopilchardus*. These terms have been found applicable in the case of the Indian oil-sardine also.

Flipping shoals.—This trait of the sardine shoals is locally called *thōlum*. The characteristic feature of the flipping shoals is the occurrence of frequent splashing noises accompanied by jerking movement of the fish in the surface waters. In this type of shoals, some individual sardines are visible at the surface and they serve to reveal the identity of the shoal. This feature of the oil-sardine shoal is almost similar to the shoals of *Sardinella fimbriata* (as observed by the author). Though flipping shoals occur both during day and night, these are more frequently seen during morning hours and nights. It appears probable that flipping adds force or momentum to locomotion within a limited area. The cause of flipping act of the individuals in the shoal is not known. It may be seen from Table I that 13 such shoals were encountered only on one occasion during this investigation, namely on 4–1–1958.

Pattering shoals.—This feature of the sardine shoal is locally known as *Kotthapudi* and such shoals were observed from October to December; and 14 such shoals were observed. Pattering is characterized by frequent small noises either simultaneous or in quick succession, which resemble the sound of big rain drops falling on the sea. Unlike the flipping shoals, there is no jerking movement followed by splashing noises in this case. Pattering is more frequent during daytime than at nights. The individuals are not visible. It may probably be an act of behaviour towards attracting more individuals of the fish for dense aggregation. Fishermen say that the shoals of *Sardinella fimbriata* also exhibit a similar feature.

Rippling shoals.—The formation of ripples is a characteristic of shoals moving at the surface and is called by the local fishermen *polappu*. Rippling

is noticed even when the wind is heavy. Some individual fish from such shoals are at times clearly discernible from a distance. Rippling areas are more clearly delimited than in the case of other types of shoals, since they are actually in contact with the surface film of water. It was interesting to see that at times many such rippling shoals moving in different directions. From the boat, the size and the direction of movement of such shoals could easily be determined. The fish from such shoals are easily caught in nets. Tiny rippling shoals may attract similar ones occurring in their vicinity and thus form a large shoal. This type of shoal was observed (a total of over 177 shoals were noticed during the course of this investigation) from October to March (Table I). The conspicuously heavy rippling produced by shoals composed of the mature sardine occurring in June is called *kadavali* by local fishermen.

Leaping shoals.—Leaping is locally called *moolel.* Some individuals from the shoal sometimes resort to leaping above the water, covering short distance (a few feet). Apart from the normal behaviour of leaping exhibited by a number of individuals in the leaping type of shoals, leaping could also be observed practically in the case of any shoal when attacked by predators and disturbed by fishing operations. Thus the leaping act normally provides a temporary escape from predators besides enhancing the overall cruising speed. The season of occurrence of such shoals was from October to March; 39 leaping shoals were encountered during the course of the work.

In addition to the above characteristics of different shoals some shoals were also distinguishable by certain colour-effects associated with them. Two types of colour-effects were observed and they are described below.

(*a*) *Bluish colouration.*—Shoals having the bluish colour are common in occurrence. During the peak of the fishery such type of slow-moving shoals are invariably encountered in appreciable numbers. Such a colouration is a characteristic of compact shoals observed during daytime; and the individual fish are not visible. These shoals are easily fishable also. Probably, this colour-effect may be caused by the incidence of sunlight on the shoal. The season of occurrence of such shoals is from October to March. Over 169 numbers of shoals with this colouration were observed during this work.

(*b*) *Pinkish colouration.*—In addition to the above-mentioned colour-effect, often times, large shoals of the sardine display a pinkish tint also which is locally called *mariyam.* It is observed during daytime. Like the bluish shoals, the individual fish are not visible and the shoal is slow-moving in this case also. Heavy catches are often obtained from shoals exhibiting this

colour-effect. In addition to the sardine shoal, shoals of *Rastrelliger canagurta* also were reported by fishermen to display a similar colour-effect. The local fishermen express the opinion that this colour is caused when the shoal disturbs the bottom mud which consequently spreads out in the same area. It was found occurring during November and December. More than thirty-one shoals of this type were encountered during this work, one on 20–11–1957 and more than thirty on 14–12–1957.

Luminescent shoals.—Besides the above-said colour-effects, luminescence (locally called *thuyyu*) was also found useful for spotting the sardine shoals; the display of luminescence by the shoals is useful during nights particularly during the dark phase of the moon. A shoal, when luminescent, appears as a patch of light (delimited by the size of the shoal) moving in the surface seas. A similar feature has been mentioned in the case of the Australian pilchard (Blackburn, 1941 and Blackburn and Tubb, 1950) and the Indian mackerel (Paradhan, 1956) also. When luminescence of the shoal is moderate, generally, the sardines are easily caught in nets. Peak of intense luminescence, locally called *thuykālem*, is considered unfavourable for fishing. Intense luminescence might enable the fish to see and avoid predators and fishing gear. This explains the unsuccessful fishing during strong luminescence. Thirty-three luminescent shoals were encountered during the course of this work, and they were seen only in November and December.

(*B*) *Bottom Shoals*

(1) *Bubbling shoals.*—Bubbling is locally known as *nurakarachel.* Though the bottom shoals are not visible, their presence can often be judged by the emergence of chains of tiny bubbles from the sea bottom and these bubbles break up at the water-surface. It appears possible that these bubbles are released from the air-bladder of the sardine through its external opening situated behind the anal aperture. Bubbling was observed in many areas in October, December, January and February. Over 118 such shoals were noticed during the course of this work (Table I). That this bubbling was associated with the sardine shoals was proved when a cast net operated in such areas invariably brought forth catches of the oil-sardine. It is noticed that the fishermen often look for this feature while trying to spot the sardine shoals; they believe that these bubbles are released by the fish from the muddy bottom while feeding at the bottom. Release of air-bubbles from air-bladder can practically facilitate the fish to sink towards lower strata of the sea. Detailed study of the air-bladder by the author has shown the occurrence of an external opening of air-bladder behined the anal aperture, and the application of gentle pressure on the bladder (when the fish is kept in water) brought

forth small air-bubbles. Whether there is any continuous release of air-bubbles through this aperture during any physiological phase of the fish is yet to be ascertained.

(2) *Fish odour*.—Sometimes, a strong fish odour locally known as *vedināttem* in an area indicated the occurrence of sardine concentrations in the bottom, while the fish were not at all visible; and the fish from such concentrations were generally netted in heavy quantities. A profuse discharge of mucus from thousands of the sardine may probably be the cause for this odour. The different individuals being attracted by the strong body odour may continue to stay together forming a compact large shoal. Such an odour occurred once during October (30–10–1957) during the present study.

Size and shape of shoals.—The sizes of various shoals encountered were only visually estimated and are hence approximate. The shoals were seen to range from 2 metres to 25 metres in length and 1 metre to 20 metres in breadth. (Two huge rippling shoals measuring about 500–800 metres in length and about 400 metres in breadth were observed on 26–10–1957.) The surface swimming shoals, being generally discernible, were studied as regards their shape and size. The front region of the shoal was usually somewhat narrow and slightly pointed; the hind end was rather blunt. It would appear that a few fish at the front portion of the shoal lead the rest, on most occasions in the case of the surface shoals especially the rippling ones. The shoals having the pattering behaviour were seen to be more or less oblong in shape. The bluish shoals appeared to be somewhat narrow and long, and their boundaries were not quite clearly visible.

Movement of shoals.—Owing to practical difficulties, the rate of movement of the individual shoals could not be determined with any degree of accuracy. However, attempts were made to study their speed by observing the time taken by them to move from one fixed point to another situated on the shore, naturally this applies only to shoals swimming parallel to the shore.

Small shoals of the sardine swimming at the surface were generally quick. Certain surface shoals were observed to have moved at the rate of about three miles (about five kilometres) per hour. The speed of shoals having bluish and pinkish tints was considerably lower than that of the rippling ones.

The directions of movement of shoals were not the same during the different months and no apparent relation to the wind or water flow (Table I) had been noticed, within the limits of observations, during the course of this study.

Vertical distribution of shoals.—A large number of shoals is found to come to the surface layers of sea at about sunset. The presence of the invisible bottom shoals is known from the occurrence of bubbling and fish odour; and they are confined to the sea-bed and it would appear that their cruising speed is considerably low. The bluish and pinkish colour-effects associated with the various surface shoals are perhaps produced or influenced by the sunlight.

Length Composition of Shoals

Table I shows average and modal lengths of *Sardinella longiceps* based on the samples taken in the cast net on the different days during the period of investigation. It is interesting to note that throughout the year under observation, small-sized sardine ranging in modal lengths from 12·0–14·5 cm. occurred in the cast net catches (of which the 13·0 cm. mode dominated; next in importance was the fish having the mode at 14·5 cm.). The average length showed a range from 12·60-14·69 cm. Since no selective fishing is involved in this case it would be reasonable to assume that the catches procured with this net are fairly representative of the sardine populations which visited the inshore fishing grounds off Calicut during the year of observations. And, Table I shows that both the average and modal lengths of the fish are very near each other in all the samples examined. Therefore, it would appear that the fish belonging to the same size-group (and age-group)* tend to shoal together. Only a small percentage (less than 10%) was formed by the big-sized fish (16·0–19·0 cm. group) belonging to other age-groups. In the case of the shoals of the Indian mackerel, Pradhan (1956) stated that in a single mackerel shoal, the variation in size is very small and that different shoals may be formed by the fish having different size-groups.

Shoaling and Predators

The various predators associated with the sardine shoals were observed to influence shoaling to some extent, and the predators were terns, dolphins and gulls in the order of importance.

(*a*) *Terns.*—Terns were found invariably hovering around the sardine shoals and picking the fish uttering shrill cries. Two kinds of them were frequently noticed.

(1) *Sterna aurantia* ? Gray.—In this case the black bloch on its head is about 6 cm. long and 5 cm. wide. The rest of the body is white in colour.

* Studies on the age of the oil-sardine (Balan, 1959) have indicated that the fish having the 13·0 cm. modal length are one-year old.

TABLE

Some observations on the shoaling behaviour of Sardinella longiceps

Date	Time of observation	Depth in metres	Temperature °C.	Turbidity cm.	Direction of water flow from	Direction of wind from	Direction of movement of shoal to	Shape of shoal
9-10-1957	12·00- 2·40 p.m.	15·0-22·0	30·00	..	S.E.	N.W.	N.E. & N.W.	Elongate and Rectangular
11-10-1957	5·00- 7·30 p.m.	10·8-15·0	29·2	..	N	do.	S & S.W.	Slightly pointed and attenuate
26-10-1957	6·50-11·15 a.m.	4·5- 5·5	29·2	..	W	E	W	Not quite distinct
30-10-1957	6·45- 9·45 a.m.	3·5- 5·5	..	..	N	do.	S & N	Elongate, slightly pointed and attenuate
8-11-1957	9·45-11·00 a.m.	5·5- 7·2	29·8	..	S.E.	S.E.	..	..
19-11-1957	9·00-11·00 p.m.	9·0-12·6	..	..	N	Calm	N	Not distinct
20-11-1957	6·40-10·45 a.m.	7·2- 9·0	29·9	..	do.	do.	W	Indistinct
21-11-1957	9·00-11·00 p.m.	9·0-15·0	..	..	do.	N	N.W.	do.
30-11-1957	8·15-10·15 a.m.	2·8-10·8	30·0	..	S.E.	S.E.	W	do.
7-12-1957	9·00-10·30 p.m.	5·5- 9·0	30·0	..	do.	do.	S	No definite shape
10-12-1957	9·00-11·00 a.m.	do.	30·0	..	do.	do.	do.	Indistinct
14-12-1957	do.	3·5- 9·0	29·0	..	do.	do.	N	do.
18-12-1957	do.	7·2-10·8	..	..	N	Calm	N.E.	do.

I

Val. (*No. of each type of shoal encountered is given in parenthesis*)

Size of shoal	Length-groups composing shoal* cm.				Characteristics of shoals	Remarks
	Min. length	Max. length	Average length	Modal length		
10 m. long and 6 m. broad	11·1	13·5	12·61	12·5	Rippling (Plenty) Bluish (Plenty) and dense shoals, each about (100)	Shoals occurred in surface waters. Dolphins sighted
15–20 m. long and about 6–8 m. broad	11·0	13·5	12·60	13·0	Rippling about (20) Pattering (8)	Surface moving
About 10–800 m. long and 8–400 m. broad	11·8	15·3	13·52	13·0	Bubbling (50>) Rippling (3) being the largest. Leaping (2) Bluish colouration (50>)	Bubbling seen scattered in large zones
12 m. long and 4 m. broad	12·0	17·4	13·52	13·0	Rippling (20) and quick moving	Besides a fish odour prevailed and very good catches obtained
..	..	..	..	..	..	No shoal observed
..	..	..	..	..	Luminescent shoal (15)	Shoal luminescent and slow moving, catch not obtained
5–20 m. long and 1–4 m. broad	12·4	18·4	13·71	13·0	Rippling (1), Leaping (2), Bluish colouration (8), Pinkish colouration (1)	Very slow moving concentrated and surface shoals; Terns found associated
Each about 25 m. long and about 20 m. broad	..	..	..	..	Luminescent shoal (8)	Slow moving
..	12·1	18·0	13·65	13·0	Rippling (2), Pattering (5)	Dolphins seen
..	12·2	18·3	14·18	14·0	Leaping (4), Pattering (1)	Terns seen
..	12·6	18·4	14·28	14·5	Leaping (7), Bubbling (3)	do.
..	11·6	19·9	14·49	14·5	Bubbling (10), Leaping (5), Pinkish colouration (30>)	do.
Each about 20 m. long and 8–10 m. broad	..	..	..	..	Luminescent Shoal (10)	Slow moving

TABL

Date	Time of observation	Depth in metres	Temperature °C.	Turbidity cm.	Direction of water flow from	Direction of wind from	Direction of movement of shoal to	Shape of shoal
4-1-1958	8·15-10·30 a.m.	3·5- 5·5	29·5	..	do.	S.E.	N	Attenuate (Flipping Shoal)
25-1-1958	8·15-10·15 a.m.	3·5- 6·3	29·0	..	N.E.	do.	..	..
1-2-1958	8·30-10·15 a.m.	3·5- 5·5	29·0	55·0	do.	do.	..	Indistinct
15-2-1958	8·30-10·45 a.m.	3·5- 9·0	29·5	40·0	S	S	..	..
18-2-1958	9·00-10·45 a.m.	3·5- 5·5	30·0	..	S.E.	do.	..	..
25-2-1958	9·00-11·00 a.m.	5·5- 7·2	29·5	..	N.W.	..	N., N.E.	Elongate
4-3-1958	8·00-10·00 a.m.	3·5- 7·2	29·0	49·0	To S	To N	..	..
11-3-1958	9·00-10·35 a.m.	3·5- 6·3	31·0	..	From N	From N	..	..
15-3-1958	5·30- 7·30 p.m.	4·5- 9·0	..	..	do.	N.W.	From N	Elongate and attenuate
18-3-1958	9·00-10·20 a.m.	3·5- 6·3	31·0	..	do.	N	..	..
* 25-3-1958	9·00-11·00 a.m.	3·5- 8·1	31·0	69·0	N.W.	N.W.	To S.E., N & N.E.	"Oblong"
1-4-1958	9·00-11·00 a.m.	3·5- 9·0	31·0	68·0	N	N	To S	Narrow and elongate
8-4-1958	8·40-10·35 a.m.	3·5- 7·2	32·0	71·0	do.	do.	..	..

Note.—From the middle of April to November 1958, these observation trips were made in bidity, etc., were maintained (collected from the inshore area, 3·5-15·0 metres).

Temperature.—Temperature ranged from 24·8° - 32·8° C., the highest recorded being in

Turbidity.—These values ranged from 44·0-251·5 cm.; the highest value observed in

Direction of water flow.— On most occasions the direction of water flow was from North to

* All the samples consisted of 100 Nos.; those on 11-10-1957 and 18-3-1958 were repre-

I—(*Contd.*)

Size of shoal	Length-groups composing shoal* cm.				Characteristics of shoals	Remarks
	Min. length	Max. length	Average length	Modal length		
About 8 m. long each and 7–8 m. broad (Flipping shoals)	11·4	14·5	12·83	12·0	Bubbling (40>), Flipping (13)	Dolphins and plenty of terns observed
..	..	..	..	..	..	No shoal observed
..	12·0	17·0	13·60	13·0	Leaping (1)	Terns observed
..	11·1	17·5	13·19	13·5	..	Catch obtained from sea bottom
Leaping shoal about 3 m. long	12·1	15·7	13·62	13·0	Bubbling (15), Leaping (11)	Terns plenty
2–4 m. long and 1–2 m. broad	12·2	17·5	13·86	13·0	Bluish shoal (7)	Slow moving and sub-surface shoal. Tern, sea gull and dolphin noticed
..	13·1	16·2	14·64	14·5	..	Shoal occurred in the bottom area
..	..	..	..	..	..	No shoal observed
Each rippling shoal about 5 m. long and 3 m. broad	13·2	16·8	14·69	14·5	Rippling (30), Leaping (5)	Terns observed
..	11·9	14·5	12·91	12·5	..	Shoal occurred in the bottom area
4–5 m. long and 2–3 m. broad	No catch obtained			..	Bluish shoal (4), Rippling (1)	Bluish coloured and Ripping at surface waters, Terns observed
4–5 m. long and about 2 m. broad	13·0	16·0	14·5	14·0	Leaping (2)	Dolphin and Sea gull seen
..	..	..	..	..	..	No shoal observed

the forenoons only; and no shoal was observed; and the routine data on sea temperature, tur-

April and the lowest in August.
November and the lowest in April.
South.
sented by only 50 Nos. each.

(2) *Sterna* ? .—This tern is lean and blackish in colour and is locally known as *mathikākka* (this means the sardine crow). These terns are extremely predatory on the sardine stocks. From the diving of these birds, it was possible to locate the sardine shoals on many occasions.

(*b*) *Sea gull* (locally known as *kadal kākka*—this means the sea-crow).—*Larus brunnicephalus* Jerdon is the common sea gull of this coast. It was also found preying on the sardine.

(*c*) *Dolphin* (locally called *ādi*).—*Delphinus delphis* was often found scattering (breaking) or disturbing the shoals. Often times, it could be seen grabbing the netted sardine. In its role as a predator upon the oil-sardine, it is perhaps comparable to the porpoise (*Phocæna vomerina*) upon *Sardinops cærulea* (Fink, 1959).

General Considerations

As in the case of British herring fishermen (Graham, 1931) the Malabar fishermen also have many beliefs regarding the sardine fishery; the latter attribute the recent prolonged scarcity (before 1957) of the sardine to the cumulative effect of continued indiscriminate fishing with the boat seine, *mathikolli vala*. In other words, they feel that this net is perhaps destructive to the fishery in the long run. The sardine are caught in *mathikolli vala* under panic impulse, as in the case of herring (as described by Graham, *loc. cit.*).

The fishermen are of the opinion that if blood and other fish waste of the sardine are dumped into the sea (as is done after the extraction of the sardine oil), the shoals will show a tendency to disappear from the inshore areas. Such disappearance or the escape reaction of the sardine, if true, can, without doubt, be attributed to their sensitivity to olfactory stimuli.

During the course of this work, the turbidity (transparency of sea) values were found to range from 40·0–251·5 cm., the lowest value being recorded in February and the highest in November 1958 (reference to Table I). High sea-turbidity, locally called *neerkalakkam*, is generally considered favourable for fishing the sardine efficaciously, since the net is invisible to the fish; it is also in agreement with the view of Graham (*loc. cit.*) with regard to herring fishery.

The temperature data showed a range from 24·8°–32·8° C. in the course of this study; the lowest recorded was in July and August, and the highest in April.

The directions of water flow recorded during the different observations showed that on most occasions it was from north to south, in the course of this work; such a direction of the flow is generally considered by the fishermen as conducive to successful fishing.

It was found that there was no traceable correlation between some of these factors and the movements of the various shoals observed in the course of the work.

Perhaps, the sardine mortality due to various predators is of considerable magnitude, and is worth investigating. In the case of *Sardinops ocellata*, an approximate estimate of the fish consumed by various predators has been made by Davies (1956 and 1957).

It can be said with confidence that very useful results can be obtained from study of behaviour characteristics of other species under natural conditions, so that such knowledge could advantageously be applied for fish-finding and successful capture.

Summary

Certain observations have been made on the features of oil-sardine shoals of Calicut during the period October 1957 to November 1958. The various kinds of shoals encountered have been described. The surface shoals were grouped as flipping, pattering, rippling, leaping, bluish, pinkish and luminescent shoals. Two categories of bottom shoals have been recognized, *viz.*, those producing bubbling and those producing fish odour. Sardine shoals could also be recognized by the presence of predators such as terns, dolphins and gulls.

A study of the size composition of sardine shoals has indicated that the fish belonging to the same size-group and age-group shoal together.

Some beliefs of the fishermen associated with the sardine fishery are given. They opine that the dumping of sardine blood and its waste into the sea during the extraction of its oil may cause disappearance of the sardine shoals; if true, this must be ascribed to their sensitivity to olfactory stimuli.

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OBSERVATIONS ON A NEW EPIDEMICAL EYE DISEASE AFFECTING THE INDIAN CARP *CATLA CATLA* (HAMILTON BUCHANAN)

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Introduction

Catla catla is one of the major carps extensively cultured in West Bengal and adjoining States of India. During the last quarter of 1959, many unusual cases of fish mortality were observed in several districts of West Bengal and preliminary investigations indicated that the fish had died due to widespread occurrence of a new type of eye disease, the infection being confined to *Catla catla* (Gopalakrishnan and Gupta, 1960). Spot surveys made at Barrackpore, Nilganj and Naihati indicated that many fish were affected by the disease and that the damage caused was considerable, about eleven metric tonnes of fish having perished during two months in these areas alone. Subsequent reports about the same disease were received from other areas like Chandernagore, Midnapore and Kancharapara also. Exact mortality figures were always not available because the fishery owners were anxious to sell off their stocks without disclosing the presence of the disease conditions, lest the fish might become either unsaleable or fetch very low prices. The epidemic was prevalent during October-January, 1959–60, and appeared again during the last quarter of the latter year.

Only few eye diseases of fishes have been described so far, the most important among them being ' Exophthalmus ' or Pop-eye, Eye-fungus, Worm-cataract and Grey-cataract (Davis, 1953; Van Duijn, 1956). The disease described in the present account does not have the symptoms or characters of other known fish diseases and has been found to occur only in *C. catla*, the other major carps like *Labeo rohita* and *Cirrhina mrigala*, which are normally cultured along with this fish, being not affected at all. Generally, specimens varying in length from 35 to 85 cm. have been found to contract the disease. Others evidently resist the infection entirely. There was only a single instance of a small catla acquiring the disease in a pond in Chandanpukur (Barrackpore).

Material and Methods

The specimens used for the present studies were obtained from Naihati, Nilganj and Barrackpore. All the fish were first examined macroscopically

and complete autopsy studies were made in all cases. Standard microbiological methods were used for isolation and study of the etiological agent of the disease (Burrows, 1950; Society of American Bacteriologists, 1957). When cultures from internal organs of the fish had to be made, fresh specimens were first placed in 70% alcohol for about 15 minutes, the alcohol ignited for 1 minute and then the flame put out. Isolations were always taken with platinum loops. Initially, cultures were made on standard agar slopes, but later on it was observed that better growths could be obtained by using fish tissue extract, which was prepared following the trout-tissue extract method adopted by Snieszko and Friddle (1950). Small specimens of *C. catla*, which had not been fed for 24 hours, were used for making the extract and the basic medium was composed of proteose peptone, tryptic digest of casein, yeast extract, maltose and sodium chloride.

Symptoms and Pathology

The eyes of the fish are the primary organs affected by the disease. Either one or both the eyes may become infected. During the early stage of the disease, a reddish colouration develops in the cornea due to vascularisation (Fig. 1). No hæmorrhage occurs. This condition lasts for some time, usually between 15 and 20 days. Subsequent to this, the whole of the cornea turns milky white in colour and becomes opaque (Fig. 2). The fish show some sluggishness at this stage and are frequently seen to move near the surface of the water. The opaque nature of the eye of living fish will be visible from above the water-surface. Further progress of the infection results in putrefaction of all tissues of the eye, starting with the cornea and lens. Ultimately the affected tissues fall off, leaving behind the hollow eye-cup with punctured walls (Fig. 3). In some specimens the opaque cornea gets punctured earlier and the putrefied contents fall through the holes (Fig. 4). The colour of the gills fades by this time and most of the fish at this stage of the disease die and float on the surface of the water.

Autopsy studies as well as dissections of specimens showing the different symptoms of the disease, revealed that the brain and optic nerves are the other organs affected. The brain cells get destroyed and the whole tissue loses its consistency (Fig. 5). The optic nerves lose their structural characteristics and appear in patches only. The infection spreads from the eyes to the brain gradually, through the optic nerves. Similar fatal infections of the brain by fish eye diseases are known in the case of Eye-fungus and Worm-cataract also (Van Duijn, 1956).

Examination of specimens collected from a tank in Nilganj showed that many of the infected fish had red inflamed spots on the skin surface, especially

at the base of the caudal and pectoral fins and also the ventral region of the abdomen. This phenomenon of occurrence of red spots, which are called ecchymoses, was found to be due to secondary bacterial infection only and had no connection with the infection of the eye, optic nerve and brain. Cultures isolated from these spots showed the presence of bacteria quite different from the organisms responsible for the eye disease and hence they do not merit attention in the present account.

All other organs of the fish are apparently unaffected by the disease. Death is rather prolonged, depending on the general condition of the fish and whether the infection started in one eye or both the eyes at the same time. Fish which contract the infection simultaneously in both the eyes die in about a week's time after the cornea turns opaque, whereas for others the period may extend up to twenty days. On an average, death occurs within seven to twelve days after opacity of cornea takes place.

Cause of the Disease

During the preliminary investigations conducted, it was noticed that cultures isolated from the affected regions of the fish showed the presence of a bacterium and an actinomycete (Gopalakrishnan and Gupta, 1960). However, further studies revealed that the actinomycete does not have any role in the etiology of the disease. An important observation made is that the bacterium could not be isolated from the eyes of the fish showing the first symptoms, *viz.*, the development of reddish colouration of the cornea. Hence at one stage it was thought that probably the disease might be virus in origin. But further observations showed that the bacterium is wholly responsible for producing the further symptoms and progress of the infection and ultimate death of the host. Diseases which are virus in origin have special characteristics (Watson, 1954), but no evidences have been obtained to suggest these organisms also as a probable cause of the eye disease. The bacteria are invariably present in the cornea that has begun to turn whitish (2nd stage of the disease), but at this time the brain of the fish is never infected. However, the bacteria begin spreading to the optic nerves in some specimens. Fish having next symptoms show the presence of the pathogenic bacteria in the brain also, the intensity of attack being directly related to the period elapsed after the disease started.

Cultures prepared from the infected eyes, optic nerves and brain showed that the etiological agent of the disease is a bacterium, which has been identified as *Aeromonas* sp. The organism was isolated in pure cultures. In certain respects it resembles *Aeromonas liquefaciens* (*Pseudomonas punctata*) and is

considered to be a variant of this species. The colonies show variations in form in different cultures. A typical growth on agar slope is shown in Fig. 6. The organisms grow well in temperatures between 18° and 24° C., and are found to be killed in 15 minutes at 30° C., 8 minutes at 35° C., 5 minutes at 40° C. and 2 minutes at 45° C. The bacterium is gram-negative in staining reaction, motile and flagellated. It stains readily with aniline dyes. The colonies are smooth, spreading, greyish and translucent. The cells vary in size, but appear as short rods 1·2 to 2·1 μ long and 0·3 to 0·7 μ broad. Experiments on inoculation of the organism in pure culture into susceptible fish to give rise to disease conditions have given varying results because in nature, only medium and large size catla are susceptible to the disease and it is very difficult to keep bigger fish alive under experimental conditions. Results of further efforts in this line will be reported later.

Incidence of the Disease in Different Sizes of the Fish

Data collected on the incidence of the eye disease in catla of different lengths are presented in Table I. From the results obtained it will be seen

Table I

Incidence of the eye disease in catla of different sizes

Length group (cm.)	No. of fish examined	No. of fish infected	% affected in total No. infected
10–20	78	1	0·32
20–30	62	3	0·96
30–40	112	22	7·03
40–50	210	108	34·50
50–60	155	82	26·20
60–70	133	68	21·73
70–80	34	21	6·71
80–90	12	8	2·55

that the maximum incidence of the disease occurs in medium and large size fish. Only few specimens were available for study in the length groups 70–80 cm. and 80–90 cm. Among these, the intensity of attack was found

to be very high. In addition to these two groups, the infection was predominant in the length groups 40–50 cm., 50–60 cm. and 60–70 cm. Only one small catla (12·5 cm.) showing the symptoms of the disease has been obtained so far. In the second length group (20–30 cm.) all the three fish found infected were about 29 cm. long and in the third group (30–40 cm.), out of the twenty-two numbers diseased, eighteen were above 35 cm. in length.

Control Measures

A series of experiments for the control of the disease was conducted in selected ponds and tanks. It has been observed that fish in which the disease is in advanced condition rarely recover. But it is possible to adopt some measures to prevent the occurrence of the infection in epidemic proportions or to arrest its progress once the disease has started to take its toll. The spread of the infection is more predominant in stocking ponds and tanks where sanitary conditions have deteriorated due to various reasons. This adverse factor gives an impetus for the epidemic to assume large proportions after rainy seasons and consequent floods, when contamination is inevitable. The influence of chemical, physical and psychical factors on outbreaks and severity of fish diseases is little known (Snieszko, 1958 *a*). However, control measures aimed at improving these conditions are known to reduce losses in stocks to a very large extent, even though they may not be able to eradicate the disease completely.

Under field conditions, group treatment is the most effective and this is preferable for economic reasons also. Among five big stocking tanks selected for control experiments, three were in Barrackpore, one in Nilganj and the other in Naihati. In the tanks selected at Barrackpore, three different methods of control were adopted. In the first, two applications of 1 p.p.m. potassium permanganate during a period of seven days gave satisfactory results and the mortality stopped after eleven days. In the second tank, application of commercial lime and artificial aeration was tried. Although the mortality rate tended to decrease, the treatment was not fully effective in checking the epidemic. Hence 0·5 p.p.m. of potassium permanganate was applied after a week. This effectively checked further spread of the disease and mortality stopped after a total of sixteen days. In the third experimental tank, the infection was in primary stages only. Since there was excess of organic debris at the bottom, this was removed first and an inflow of sewage drainage was blocked. The fish showing symptoms of the disease were segregated and given one-hourly baths of Chloromycetin at a concentration of 8 milligrams per litre, for three consecutive days. The

water in the tank was treated with potassium permanganate (1 p.p.m.). These measures were very effective and the disease disappeared in the tank after a period of fourteeen days and there was no mortality due to the eye disease. In the tank selected at Nilganj, the sanitary conditions were first improved and two subsequent applications of 0·5 p.p.m. potassium permanganate stopped the progress of the epidemic after 12 days. During this period the rate of daily mortality of fish was found to decrease gradually. In the tank at Naihati, most of the big catla had contracted the disease. Of these, seventy-six numbers were in advanced stages and they were destroyed. Others were given one-hourly baths of Chloromycetin (10 milligrams per litre concentration) for three days. Three weekly applications of 1 p.p.m. potassium permanganate were also made. Although thirty-three fish died during this period, eighty-two were estimated to have been saved from the epidemic by the end of the experiment.

On the basis of the results obtained from these experiments, similar group treatment measures were recommended to several private farmers and generally satisfactory results were obtained.

Discussion

Among the few eye diseases of fishes that have been investigated earlier (*see* Davis, 1953; Van Duijn, 1956), Exophthalmus is the most serious complaint and has been found to cause large-scale mortality in trout hatcheries, there being various forms of the disease (Davis, 1953; Wolf, 1957). The eye disease of *Catla catla*, which also has now been found to cause severe epidemics, is quite different from Exophthalmus with regard to the symptoms and pathology (Davis, *loc. cit.*). It is significant that while Exophthalmus affects many internal organs of the fish, especially kidney, liver and spleen, the catla eye disease damages only the eyes, optic nerves and the brain. There has been no trace of any fungal attack in these tissues of the fish showing symptoms of the disease.

That this eye disease has been found so far to affect *C. catla* only is an interesting observation. Particular care has always been taken to examine thoroughly other fishes present in all the ponds and tanks in which the disease has been studied and not even in a single instance, the symptoms or the disease conditions could be observed. Specificity of fish diseases is common, but generally they are found to be prevalent in allied groups of fishes. As a general rule, it may be stated that a pathogenic bacterium is limited to a small number of hosts (Burrows, 1950). The fish kidney disease had earlier been found to cause serious mortality of brook trout, but eventaully the infection was

found to occur in brown trout and rainbow trout also (Griffin, 1954). Dropsy disease of fish, which may assume different forms, has been recorded to cause serious epidemics of *Cyprinus carpio* (Schäperclaus and Mann, 1939). Similarly, although ulcer disease is common among trout, the brook trout *Salvelinus fontinalis* has been shown to be particularly susceptible to the disease (Snieszko and Friddle, 1950). A new bacterial disease caused by *Gaffkya* has been recorded to affect the lobster *Homarus americanus* only (Snieszko and Taylor, 1947). An epidemic disease of rainbow trout, *Salmo giardnerii*, in Japan has been found to be due to *Vibrio piscum* var. *japonicus* infection (Hoshina, 1957). To cite another instance is the occurrence of the peduncle disease in the fingerlings of rainbow trout only (Davis, 1953).

It appears that among the major carps cultured in Indian waters, *Catla catla* is the least resistant to bacterial infection. This has been noticed in the case of Dropsy, fin-rot and tail-rot diseases also (Gopalakrishnan, unpublished observations). Among all animal populations there are groups, strains or individuals which are either temporarily or permanently resistant to infectious diseases (Snieszko, 1958 *b*). Resistance to such diseases is also made up of a number of factors like age, seasons, nutritional well-being, etc. (Burrows, 1950). Even a blood component called properdin has been found to have influence on non-specific resistance to the infections (Snieszko, 1958 *b*). Further, both the pathogenic organisms and their hosts are considered to be organised and get their characteristics of pathogenicity and susceptibility (or resistance) from the development of an inheritance made up of distinct genes (Gowen, 1952; Snieszko, 1958 *a*). However, as has been pointed out by Snieszko (*loc. cit.*), it should be borne in mind that the influence of genetic factors are liable to be modified by various other factors like availability of dissolved oxygen, presence and concentration of pollutants, density of population, etc. The natural resistance of fishes to infectious diseases has engaged the attention of workers during recent years only and further studies in this direction will be very valuable in the control of diseases.

The occurrence of the eye disease of *C. catla* is found to be seasonal in nature, the maximum intensity of attack being during the months October, November and December. The production of antibodies in fishes is affected by changes in temperature of the water and this is one of the factors responsible for the seasonal appearance of the disease (Snieszko, 1954). Experiments made on the etiological agent have indicated that the organism grows well between 18° and 24° C. and that it perishes at higher temperatures. Hence it will be noticed that the temperature conditions in the Inland Fish culture areas of West Bengal become suitable for the growth and spread of

the bacteria immediately after the rainy season. The fish become least resistant during this time due to deterioration of sanitary conditions also.

Most of the bacterial fish diseases are caused by motile or non-motile gram-negative bacteria (Griffin and Snieszko, 1951). The etiological agent of the eye disease of *C. catla* is most probably a variant of *Aeromonas liquefaciens*. The author, while making studies on other epidemical diseases of Indian carps, has noticed a close relationship between Exophthalmus and Dropsy diseases (Gopalakrishnan, unpublished observations). The cause of the former disease also appears to be a species of *Aeromonas*. Earlier studies on Dropsy have indicated that the etiological agent for infection of *Cyprinus carpio* is *Pseudomonas punctata* (Schäperclaus and Mann, 1939), but later investigations (Snieszko, 1954) showed that the name *Aeromonas liquefaciens* should be applied to the bacterium. In view of the relationship observed between Dropsy and Exophthalmus, it is understandable that an organism allied to the causative agent of these diseases is responsible for a different type of eye disease showing other pathologic conditions.

The fact that no bacteria could be isolated from the eyes of catla showing the earliest symptoms of the disease tends to show that although the infection is caused by a bacteria, other factors are associated with its pathogeny. Generally, the presence of a virus is suspected in an infectious disease only when bacteria or other organisms are not isolated (Wolf, 1957). There have been no indications or evidences to show that any virus is associated with this eye disease, and the symptoms and the effectiveness of Chloromycetin treatment also support this (Snieszko, 1953; Watson, 1954). On the other hand, it is felt that the state of nutrition of the host fish has an important effect on the origin and development of the disease. The role of vitamins in prevention of infections is not well known, but a few investigators have been able to demonstrate that avitaminosis causes the diminution of production of antibodies, thereby reducing the resistance of fishes to diseases (Halver, 1954). Riboflavin deficiency results in corneal vascularisation, cloudy lens, hæmorrhagic eyes, etc., in salmon and trout (Halver, *loc. cit*). The first symptoms noticed in the case of the eye disease of catla is vascularisation of the cornea and then opacity of the tissue. These may develop due to avitaminosis and this probably explains the absence of bacteria in isolates taken at this stage. Since the food habit of catla is different from that of rohu and mrigal, nutritional deficiency of the species also is likely to be an important factor for the susceptibility towards the disease.

Sulphonamides and Antibiotics are the best known and most effective weapons against bacterial diseases of fishes. The other control measures

generally adopted are sanitation, immunisation and serotherapy (Snieszko, 1954, 1958 *b*). Economic factors go against the use of sulpha drugs and antibiotics under field conditions. The encouraging results obtained by the author show that emphasis can be laid on the cheaper methods like proper sanitation and prophylaxis. Chloromycetin baths at a strength of about 8 to 10 milligrams per litre, if practicable, is the best for curing the disease, at least in the earlier stages of infection. For this, the fish have to be isolated and given one-hourly treatment for two or three consecutive days. Since this may not be acceptable to many of the Indian Fish Farmers, the following easier methods can generally be recommended. All fish showing advanced stages of the infection should be removed and destroyed. Then efforts must be made to improve the sanitary condition of the area and the water should be thoroughly disinfected to avoid further spread of the epidemic. Application of potassium permanganate solution to a strength of 1 p.p.m. will be effective in this respect. The dissolved oxygen content also will be increased by this application and if sufficient food is not available for the fish, efforts should be made to boost up the plankton, because catla is mainly a plankton feeder.

Study of diseases of Indian fishes is still in its infancy and practically very little work has been done on the epidemic diseases. Large-scale mortality of fishes due to infectious diseases is common in many parts of the country, and with the increase in fish cultural practices, infections caused by bacteria, fungi, etc., also tend to make frequent appearances. With advances in fish pathology, more and more diseases are likely to be described (Snieszko, 1958) and thus the eye disease of *C. catla* has now been found to be an important fish disease, which may cause heavy damage unless proper prophylactic and control measures are adopted.

Summary

The occurrence and symptoms of a new eye disease which causes large-scale mortality of the Indian carp *Catla catla* have been described in detail. The disease affects the eyes, optic nerves and brain. Death of the fish is caused by damage to brain tissue. Generally catla varying in length between 35 and 85 cm. are susceptible to the disease.

The etiological agent is a bacterium and is considered to be a variant of the species *Aeromonas liquefaciens*. The organism shows differences in form, is gram-negative, flagellated, motile and is most active at temperatures between 18° and 24° C. Ecological factors and avitaminosis are connected with the susceptibility to infection.

Control methods using Chloromycetin baths (8–10 mg. per litre), application of potassium permanganate (1 p.p.m.), improvement of sanitary conditions and stabilisation of other factors like dissolved oxygen content, have given satisfactory results.

The specificity, etiology and pathology of the disease and influence of ecological and nutritional factors are discussed. Recommendations to fish farmers for the prevention and control of the epidemic have also been given.

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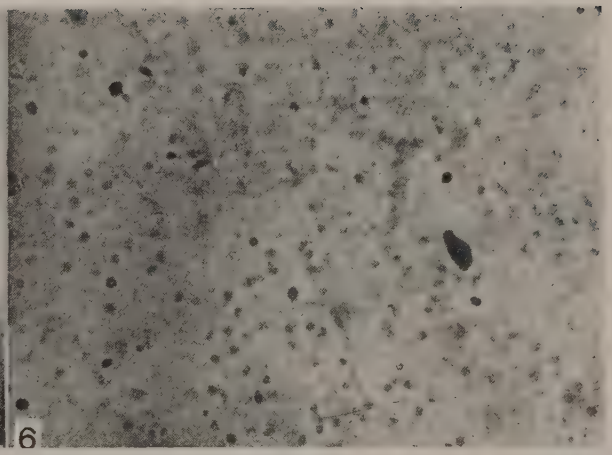
FIGS. 1-4. Fig. 1. A catla showing the first symptom of the disease, *viz.*, vascularisation of the cornea. Fig. 2. Second stage of the eye infection, when the cornea has become white and opaque. Fig. 3. Fish showing the advanced condition of the disease, the eye having been completely destroyed. Fig. 4. Portions of the cornea are left behind, the other parts of the eye having been destroyed.



FIGS. 5–6. Fig. 5. Cranial dissection of a freshly killed catla showing advanced symptoms of the disease. The brain has been damaged and lost its consistency. The brain tissue has partly drained out. Fig. 6. Colonies of the pathogenic bacteria on nutrient agar.

EVALUATION OF TOXICITY OF SOME INDUSTRIAL EFFLUENTS TO FISH BY BIO-ASSAYS

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Introduction

Determination of minimal lethal doses of industrial effluents which kill test animals in a particular period, is necessary in setting up standards for safe disposal of such wastes. Keeping in view the quality of water in the river, its volume, flow and the nature of soil in the river-bed, such standards can greatly help in conserving fish populations in our rivers. It is only with the help of bio-assay experiments, that toxicity limits of any pollutant substance in an effluent can be established by evaluating the median tolerance limit or " TL_m " for the particular waste which being diluted in water to a known extent, causes 50 per cent. mortality of the test fish in a specified time. The TL_m values are thus obtained by straight line interpolation from points representing per cent survival of fish and log concentrations of material in question which bracket the 50 per cent survival point (Henderson and Tarzwell, 1957).

The present communication refers to bio-assay experiments conducted with Sugar and Distillery wastes of S.K.G. Sugar Mills, Hathua, North Bihar and with wastes of Pulp and Paper Mills of Rohtas Industries, Dalmianagar, Dehri-on-Sone, South Bihar. The methodology followed in conditioning test fish, duration of experiments, oxygenation and so forth, was the same as in a previous communication (David and Ray, 1960). Effluents were analysed by the standard methods of American Public Health Association (1955).

Composition of Effluents

Sugar and Distillery Wastes.—In the process of manufacture of Sugar, extracted juice of sugarcane is treated with lime and sulphur dioxide (known as Carbonation and Sulphitation process) for clearing various unwanted ingredients such as lime salts, coagulated albumen made up of varying proportion of fats and waxes, and also the colouring matters (produced by decomposition of reducing sugar).

The ' massecuite ' thus prepared is then centrifuged to separate sugar from inextractable sugar molasses. The latter is pumped into separate tanks where it is fermented with yeast at low pH (4·5) to extract alcohol. The liquid sugar waste, having a pH of about 8·0, contains among other things, soil, variable quantities of cane fibre, cellulose, lime, carbonate and phosphate of calcium, lactic acid and oil from the machines.

Pulp and Paper Wastes.—While the process for Pulp and Paper manufacture as adopted in the Rohtas Industries has already been discussed by Motwani *et al.* (1956), it is sufficient for the purpose of this paper to give a very brief summary. The mass containing bamboo chips after digestion with caustic soda, sodium sulphide and sodium sulphate is filtered, washed and chlorinated. The exhaust cooking liquor known as ' black liquor ' containing 80 per cent alkali is treated in the soda recovery plant to recover the alkali. The waste water from Pulp Mill containing about 20% of the total alkali used in the process include besides cellulose fibres, lignin, mixtures of various sodium salts of carbonates, sulphide, sulphate, chloride, methyl mercaptan and free chlorine in solution. The liquid waste from the Paper Mill contains, among others, cellulose, lignin and sizing materials such a resin soap, alum, china clay, starch, and sodium silicate. The two types of wastes are allowed to flow into the river through a common drain.

Samples of Sugar and Distillery wastes were collected from the main effluent drain outside the factory while Pulp, Paper and combined Pulp and Paper wastes were collected separately from their respective drains inside the factory premises immediately before setting up the bio-assay experiments and the chemical analysis of each of the above type of effluents is shown in Table I. In all the experiments, oxygen level, in the solutions tried, was maintained between 5·0 and 8·0 p.p.m.

Experimental Results

Puntius sophore (Ham.) was used as test fish for the experiments with sugar and distillery wastes and *Puntius sophore* and *Mystus vittatus* for experiments with Pulp and Paper and their mixture. It would have been ideal if experiments could have been conducted using both the species in all the liquors. But because of non-availability of *Mystus vittatus* in the vicinity of Hathua, where bio-assay experiments on Sugar and Distillery wastes were conducted, only *Puntius sophore* was used.

Effluents, individually from the Sugar and Distillery plants, Pulp and Paper plants separately and the combined effluent of Pulp and Paper were

TABLE I

Showing the chemical and physical factors of different types of waste liquors collected at the time of conducting experiments

Type of wastes	Appearance	pH	Transparency		Oxygen absorbed		Total solid	Dissolved solid	Suspended solid	Loss on ignition	Total fixed solid
			Settled	Shaken	3 mts. at 27° C.	½ hours at 100° C.					
Sugar Waste ..	Milky white	7·9–8·0	∠100	∠100	50–65	60–98	3000–3944	1998–2112	1500–1832	132–188	3600–3756
Distillery Waste ..	Brown	5·0–5·3	3000–3500	4000–5000	1600–1754	2900–3300	15908–16804	4892–4964	1761–1840	3950–4856	10982–11948
Pulp Waste ..	Light brown	9·2–>9·6	Clear	310–350	..	7–10	1198–1668	860–1564	402–690	..	..
Paper Waste ..	do.	7·9–8·0	do.	650–850	..	7–18	1034–18658	504–724	530–17894	..	..
Combined Waste of Pulp and Paper	do.	7·9–8·0	do.	100–700	..	9–20	894–1266	684–1184	82–274	..	..

Type of wastes	Alkalinity			Mercaptan	Free chlorine	Sulphide		B.O.D.	D.O.	Nitrogen	
	OH	CO_3	HCO_3			S	H_2S			Amm. N.	Alb. N.
Sugar Waste ..	..	..	1600–1700	..	..	..	..	650–820	Nil	0·2–2·5	0·1–0·4
Distillery Waste ..	..	..	3980–4000	..	..	112–180	8–12	8090–8750	Nil	2·9–3·3	1·9–2·1
Pulp Waste ..	20000–40000	..	*176–11000	Present	60–71	..	..	80–100	4·5–5·0	1·0–1·2	1·0–3·3
Paper Waste ..	..	..	84–232	..	..	..	..	45–124	6·0–6·8	1·2–2·4	1·2–1·6
Combined Waste of Pulp and Paper	..	..	56–252	..	..	..	..	130–200	4·6–5·0	1·2–2·0	1·2–2·5

Results are expressed in p.p.m. * Other alkalinity expressed as bicarbonate.

diluted to evaluate the TLm value for a period of 24 hours with adequate control. Table II gives the analysis of diluents used.

TABLE II

	pH	Dissolved Oxygen p.p.m.	Alkalinity p.p.m.	Hardness p.p.m.
Diluent for Sugar and Distillery ..	7·9	8·0	280	92
Diluent for Pulp, Paper and Combined effluent of Pulp and Paper	7·9	10·0	100	90

Sugar Waste.—Sugar waste, without any dilution but in which oxygen level was maintained at about 5·0 p.p.m., has been found to be harmless to *Puntius sophore*. No mortality was discerned in the 24-hours period although the test fish exhibited some discomfort as reflected by darting movements in the initial period up to 30 minutes which might have been due to interference by gill movements caused by suspended matters present in the waste. Subsequently, such abnormal movements became progressively less frequent and at the termination of the experiments the test fish were almost normal.

Distillery Waste.—The various concentrations used in the present test were 2·11, 2·45, 3·31, 4·47, 6·03, 8·14 and 10·98 per cent. The liquor when oxygenated is characterised by having a foamy surface with a black precipitate-like gelatinous substance, the liquor taking considerable time to attain oxygen saturation. Even though sufficient oxygen was maintained the test fish within short period of their introduction exhibited rapid but unrhythmic gill movement and showed signs of distress by gulping air at the surface. Subsequently fish became moribund remaining overturned at the bottom and did not respond to physical touch with glass starring rod. These distressing movements were all the more acute in 10·98 per cent and the first mortality in this solution occurred after 30 minutes with all the 10 fishes succumbing within 1 hour and 50 minutes. In 8·14 per cent solution the first mortality was observed after 3 hours of the start of the experiments and 70 per cent of the fish died within 13 hours and in 6·03 per cent solution, 40 per cent of the fish succumbed in 15 hours but in subsequent lower concentrations, the mortality was insignificant. Thus the lethal limit varied between 8·14 and 6·03 per cent.

Pulp Waste.—The concentrations used were 20·00, 23·24, 26·99, 31·34, 36·41 and 42·30 per cent for *Puntius sophore* and 26·99, 31·34, 36·41, 42·30

and 49·12 per cent for *Mystus vittatus*. Immediately after introduction, *Puntius sophore* showed definite symptoms of restlessness as reflected by rapid but erratic opercular movements and short jerky actions. In some individuals which frequently dashed against walls of the experimental jars the sense of balance appeared to have been impaired. Subsequently these active but erratic movements became progressingly very lethargic and the fish remaining in almost vertical position with head tend upwards and the tail touching the bottom of the jar. The fish thereafter became immobilised and settled at the bottom. This type of reaction in the test fishes was clearly seen in the concentrations 42·30, 36·41 and 31·34 per cent. The first mortality in 42·30, 36·41 and 31·34 per cent concentrations of Pulp waste was observed after 4 hours and the cent per cent immobilisation took place by 9 hours. In the lower concentrations of 26·99 and 23·24 per cent, however, the first mortality occurred after 9 hours, but only 10 per cent succumbed in 23·24 per cent solution within 24 hours. In concentrations lower than this no mortality was discerned. The toxicity range for *Puntius sophore* has been determined to range between 23·24 and 26·99 per cent. *Mystus vittatus*, however, reacted in the experimental solutions somewhat differently; while the opercular movements were rapid and erratic the fish moved about rather slowly. The first mortality was observed after 2 hours, and 10 per cent succumbed within 9 hours and 90 per cent in 19 hours in 49·12 and 42·30 per cent. Thus the toxicity range was between 31·34 and 36·41 per cent which is definitely higher than *Puntius sophore*.

Paper Waste.—The pattern of fish behaviour in various concentrations of paper waste which was lethal within 24 hours was more or less the same as has been observed in Pulp waste except for the fact that here the action was delayed. The experiments however, showed that *Mystus vittatus* is hardier of the two, *e.g.*, in 36·41 per cent solution first mortality in *Puntius sophore* was observed after 3 hours as against 6 hours in *Mystus vittatus*. Likewise in 31·34 and 26·99 per cent solution, first mortality in *Puntius sophore* was noticed after 6 hours and in *Mystus vittatus* after 9 hours.

Combined Pulp and Paper Waste.—The concentrations of the effluent used were 14·83, 17·21, 20·00, 23·24 and 26·99 per cent. Both the species exhibited same pattern of behaviour as described in the case of Paper waste. The toxicity level was determined to be between 20·00 and 23·24 per cent.

Certain ill-effects of Pulp and Paper wastes when mixed in river-water, where various fishes are subjected to prolonged exposure, are mentioned by David (1957) and Motwani *et al.* (1956).

The details of toxic range, test fish used, their average size and weight are given in Table III.

TABLE III

Showing median tolerance range of test fish to different types of waste liquors

Nature of liquors	Range of Temp. °C.	Toxic Range	Median Tolerance limit	Test fish used	Size Range in mm.		Weight Range (gm.)	
					Min.	Max.	Min.	Max.
Sugar Waste ..	No mortality in original effluent							
Distillery Waste ..	19–25	6·03– 8·14	6·7	*P. sophore*	65	96	5·6	16·5
Pulp Waste ..	21–25	23·24–26·99	25·4	do.	38	73	0·6	4·2
do. ..	do.	31·34–36·41	34·7	*M. vittatus*	45	93	0·6	6·9
Paper Waste ..	do.	23·24–26·99	24·5	*P. sophore*	38	70	0·5	5·0
do. ..	do.	23·24–26·99	26·5	*M. vittatus*	38	90	0·6	6·2
Combined Waste of Pulp and Paper	do.	20·00–23·24	20·8	*P. sophore*	36	71	0·5	6·2
do. ..	do.	20·00–23·24	26·6	*M. vittatus*	45	91	0·7	7·3

Test of significance applied to different survival rates of the two species *Puntius sophore* and *Mystus vittatus* calculated on the basis of observed data on the same lines as in an earlier communication (David and Ray, *op. cit.*), show that only in Pulp liquor it is quite significant at 5 per cent level ($F = 30 \cdot 9$).

DISCUSSION

As Ellis (1937) states, pollutants injure fish mainly in three ways, *i.e.*, (i) by causing respiratory and circulatory failure through interference with excretory functions of the gills, (ii) by specific toxic action after absorption through gills or lining of mouth and other external structures, and, finally (iii) toxic action after absorption through the gastro-intestinal tract.

Distillery liquor corresponds to vegetable tan liquor in its effect upon the test fish (David and Ray, *op. cit.*) and in having a high rate of oxygen consumption (1600–1754 p.p.m., 3 minutes permanganate value, *cf.* Table I). Distillery waste of low pH 5·0–5·3 has high sulphide value and some free H_2S and even after dilution with water of pH 7·9 the waste is likely to contain some free H_2S in sufficient concentration as to be injurious to fish. Southgate (1948) reported: " In water containing 3·2 p.p.m. sodium sulphide, trout overturn in 2 hours at pH 9·0, in 10 minutes at 7·8 and in 4 minutes at pH 6·0 ". In the present series, the first mortality was observed after 30 minutes

in 10·98 per cent concentration, after 3 hours in 8·14 per cent and after 4 hours in 6·03 per cent. In still lower concentrations, while negligible mortality (10 per cent.) discerned with the experimental period, the test fish nevertheless exhibited narcotic effect being sluggish and inactive in movement. It may be mentioned that Distillery wastes contain high loads of suspended matter (*cf.* Table I), and the high concentration of suspended matter in the presence of low dilutions of toxic H_2S might perhaps result in mortality among test fish (Ellis, 1937; *Water Quality Criteria*, 1957).

Raw sugar effluent, however, did not show any ill-effects provided saturated amount of dissolved oxygen was present, otherwise, the normal sugar wastes proved lethal to fish immediately as dissolved oxygen was not present.

In Pulp effluent, traces of mercaptans were present along with a high value of chlorine which during dilution might have been free from exerting any ill-effects. It is probably this chlorine which was responsible for fish mortality. The fish behaviour also suggests this because during the course of an experimental assay with textile bleach liquor, a low value (0·08 p.p.m.) of chlorine was found toxic (David and Ray, *op. cit.*). Paper and combined effluents from Pulp and Paper plants were toxic in the sense that, unlike heavy suspended matters, the fine colloidal particles like cellulose, lignin, etc., effected the gills by clogging. Suspended matter might have also exerted some synergetic effect after entering the gastro-intestinal tract. Combined effluent of Pulp and Paper did not show presence of any chlorine. This is borne out by the fact that test fish when treated with these effluents after filtration did not show any ill-effects even in the original liquor. All three original liquors (Pulp, Paper and combined waste of Pulp and Paper) always had a good amount of dissolved oxygen (Table I) unlike all other liquors tested so far. This further shows that the Pulp and Paper effluents do not decompose quickly.

Mystus vittatus has proved undoubtedly to be hardier than *Puntius sophore*.

Summary

Experimental assays were conducted with the effluents of Sugar, Distillery, Pulp and Paper wastes. TL_m values are given. Sugar wastes did not prove lethal to test fish provided some oxygen is provided. Distillery wastes require a good amount of dilution of at least 12 to 17 times. Pulp, Paper and combined effluent of Pulp and Paper need at least 4–5 times dilution to avoid risks of undesirable effects upon fish.

Chlorine present in the Pulp liquor is harmful to fish even in low concentrations. Presence of colloidal suspended matters in Pulp effluents, if allowed

as such into the river, accelerates the toxic effects of chlorine. But since Pulp and Paper effluents are usually mixed and also highly diluted, presence of chlorine could not always be detected in combined effluent. Similarly mercaptans detected in traces in the original liquor were found absent in the combined effluent. Paper and combined effluents of Pulp and Paper were injurious only because of finely suspended particles which clog the gills and probably by synergetic action caused after entering gastro-intestinal tract when fish strived hard to take oxygen by gulping. This was further corroborated by filtered effluents not showing any ill-effects to the test fish.

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SPOILAGE OF PRAWNS AT 0° C. AND ITS ASSESSMENT BY CHEMICAL AND BACTERIOLOGICAL TESTS

By N. K. Velankar,* T. K. Govindan, P. N. Appukuttan and K. Mahadeva Iyer

(Central Institute for Fisheries Technology, Ernakulam)

Studies on the spoilage of iced prawns and its assessment by objective tests were reported earlier (Velankar and Govindan, 1959). These studies revealed that considerable losses of 'extractives' such as the free amino-acids occur during storage of prawns in ice due to leaching. Work done in the U.S.A. (Collins *et al.*, 1960) and in India (J. R. Iyengar *et al.*, 1960) has also shown that water-soluble chemical compounds including those produced through spoilage leach out during storage in ice. In order to evaluate accurately the development of the spoilage products it is necessary to carry out the investigations on prawns held at 0° C., *i.e.*, the melting point of ice, without contact with ice. The results of these studies carried out by us are reported in the present paper.

Materials and Methods

Fresh prawns obtained from the catches made by fishing boats operating from Manasseri (Fort Cochin) and from the trawlers operated by this Station in the sea off Cochin were used in these studies. The prawns were kept iced from the time of catching till they were used for the experiments, the duration not exceeding 4 hours. The prawns were kept whole, unless otherwise stated (see following) in small flat (thickness less than 1 inch) tin cans which were closed and then placed embedded in crushed ice in an insulated box for the duration of the experiment. The temperature inside the cans reached 0° C. within 2 hours after being placed in the crushed ice.

The bacterial count, trimethylamine (TMA), total volatile nitrogen (TVN), volatile acid number (VAN), free alpha-amino-acid nitrogen and the acid-soluble orthophosphate were determined at suitable intervals during the storage period. The sampling procedure and the analytical methods employed were as described by the authors in a previous paper (Velankar *et al.*, 1961).

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Results

The pattern of the development of the various spoilage indices in whole prawns are shown in Fig. 1. The curves are based on data obtained in several experiments.

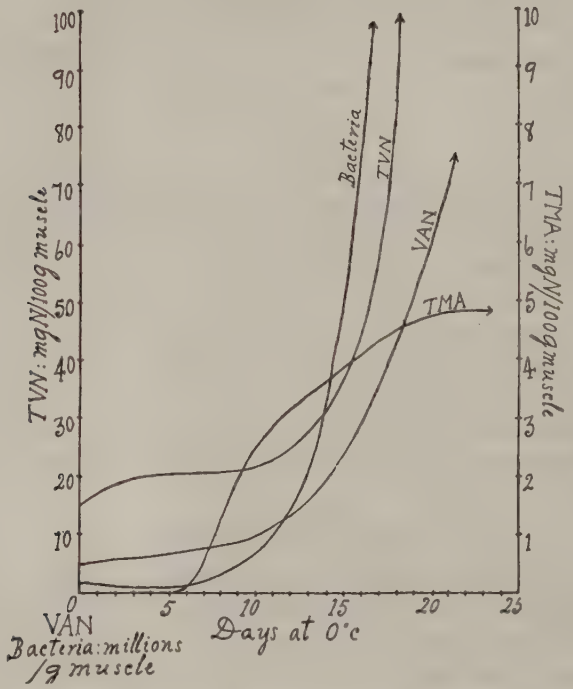


Fig. 1. Spoilage of whole prawns at 0° C.

The bacterial count decreases in the initial days of storage and begins to increase after 5 days; in about 12 days the count reaches the order of 10 million bacteria per gram of muscle. After this period the count increases rapidly to about 100 million by the 15th day of storage. The TMA is not present initially but is detectable after 5 days in storage. The TVN shows a small increase in the first 3 days of storage; after 10 days it begins to increase rapidly. The VAN which is initially less than 5 increases slowly to 10 in ten days; after this period it increases more rapidly. During storage the prawns begin to darken from the 2nd day, the percentage incidence of melanosis reaching almost 100 by the 6th day. At this time the prawn meat at the point where the head is broken off is observed to be yellow, presumably

due to autolytic spoilage. The odour becomes deep at this period though not markedly offensive.

The rise in each of the spoilage indices observed in some typical experiments is shown in Figs. 2–5 in order to illustrate the manner in which they develop.

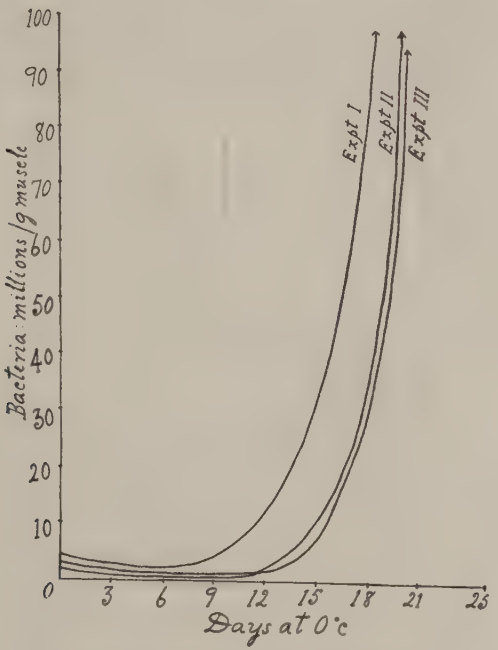


FIG. 2. Bacterial count of whole prawns at 0° C.

Commercially, besides whole prawns, prawns in ' headless ' and ' peeled ' condition are held in ice storage prior to processing, the storage duration depending on several variable factors. Investigations were therefore carried out on peeled prawns kept in tin cans embedded in ice as in the case of the whole prawns. The spoilage patterns of the peeled prawns held at 0° C. is shown in Fig. 6. Significant rise in the bacterial count, the TMA and TVN occurs only after about two weeks storage; the VAN remains characteristically low up to nearly three weeks, the value at the end of this period being about 10. Other differences are also present in the spoilage pattern of whole and peeled prawns (see following).

In order to obtain strictly comparable data on the spoilage pattern in prawns held whole, headless, and peeled conditions respectively prawns

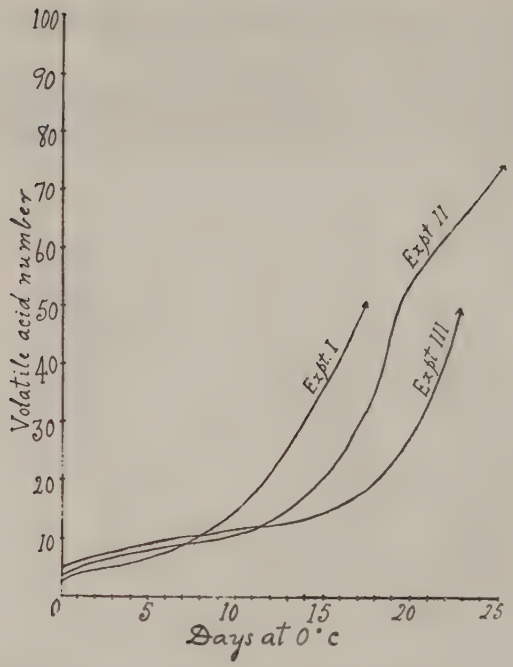


FIG. 3. Volatile acid number of whole prawns at 0° C.

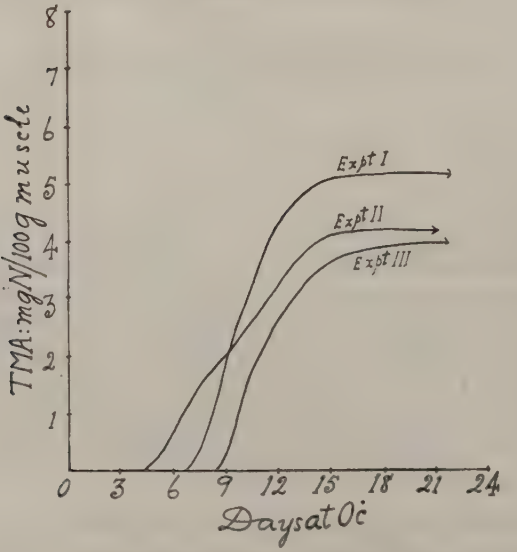


FIG. 4. Trimethylamine increase in whole prawns at 0° C.

belonging to a single species, *i.e.*, *Metapenæus dobsoni*, from a single haul were employed and experiments conducted simultaneously keeping these in cans embedded in ice as in the previous experiments. The development of the spoilage indices in these studies are shown in Figs. 7–10. Increase in the bacterial count occurs simultaneously in the whole and headless prawns; in peeled prawns it occurs a little later. Increase in the VAN occurs much earlier in the whole prawns than in the peeled prawns; in headless prawns the increase is intermediate between that in whole and peeled prawns. The TVN also increases more rapidly in whole prawns than in the peeled prawns.

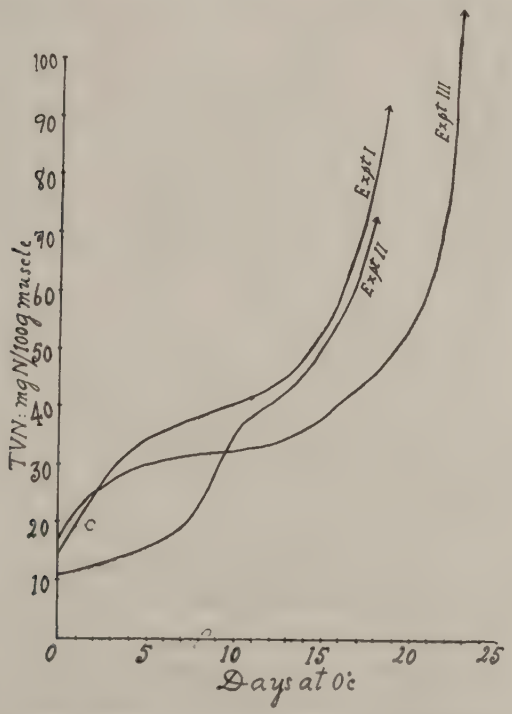


FIG. 5. Total volatile nitrogen increase in whole prawns at 0° C.

The TMA rises simultaneously in the whole and headless prawns; in the peeled prawns it is detectable only after about 20 days whereas in the whole and headless prawns it is detectable after 3 days. Incidence of melanosis was far less in the headless prawns compared with whole prawns.

The pattern of the changes occurring in the free amino-acid nitrogen content of prawn muscle during storage of whole prawns at 0° C. without

contact with ice is shown in Fig. 11. The amino nitrogen increases slowly from the initial value by about 50 mg. N/100 g. muscle in about three weeks after which it begins to decrease. Changes in the orthophosphate of the muscle occurring in whole and peeled prawns respectively are shown in

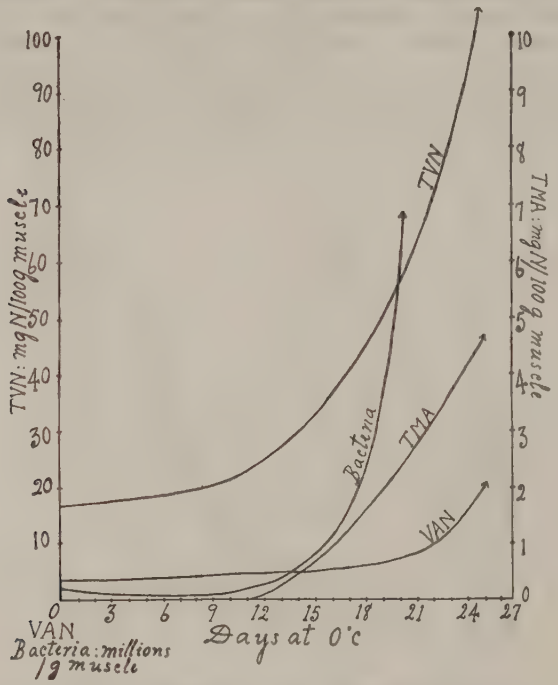
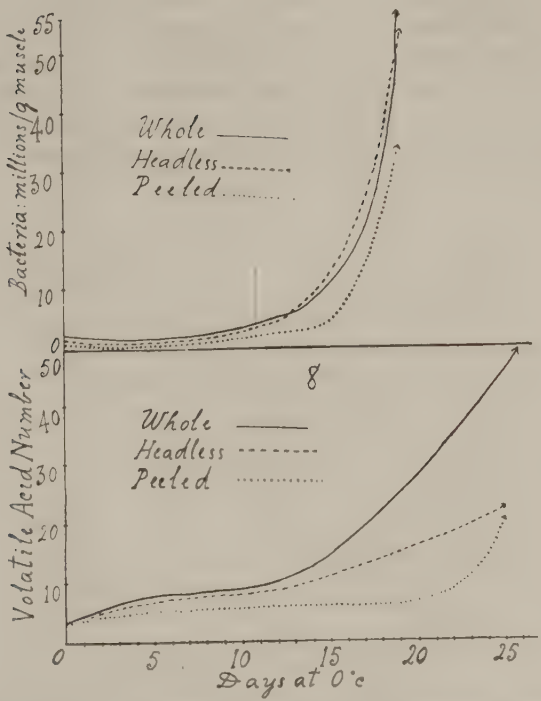


FIG. 6. Spoilage of peeled prawns at 0° C.

Fig. 12. In whole prawns the phosphate falls sharply after 4–5 days storage and continues to decrease thereafter at a much slower rate. In the peeled prawns no decrease in the orthophosphate occurs during storage at 0° C.

In order to compare the values of the spoilage indices during storage of prawns at 0° C. without contact with ice with the values observed in the case of prawns held in ice, some observations were carried out on whole prawns kept in ice. The results of this study are shown in Table I. In the earlier work on iced prawns carried out by Velankar and Govindan (*loc. cit.*) the spoilage indices studied did not include the volatile acid number.

Comparison of the figures in Table I with the observations recorded for prawns held at 0° C. without contact with ice shows the values for the iced prawns to be lower than for the uniced prawns after equal duration at 0° C.



FIGS. 7–8. Fig. 7. Bacterial count. Fig. 8. Volatile acid number.

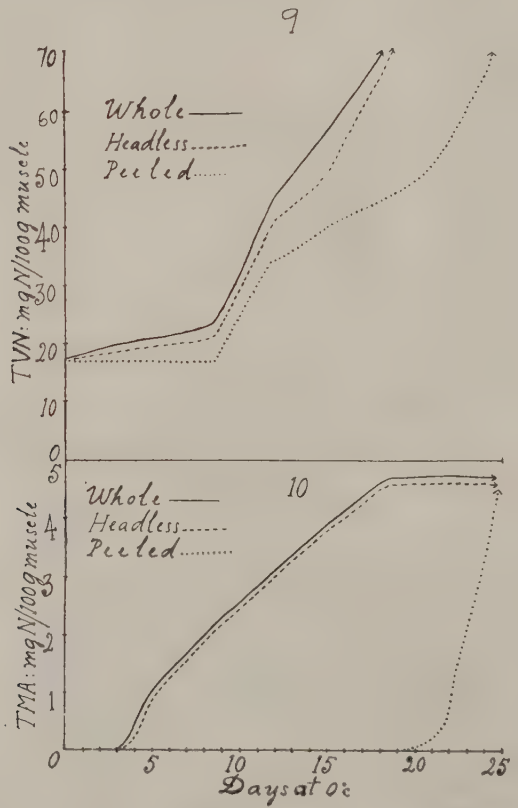
TABLE I

Spoilage of iced prawns

Days in storage	Bacterial count (million per g. muscle)	Trimethylamine (mg. N/100 g. muscle)	Total volatile nitrogen (mg. N/100 g. muscle)	Volatile acid number
0	0·54	nil	13·54	2·29
3	0·34	,,	11·78	1·91
6	0·20	,,	8·61	1·91
11	0·134	,,	7·35	1·06
17	1·698	,,	3·71	0·92
21	5·20	,,	5·68	5·36
24	13·0	0·5	6·3	7·72

Discussion

The period elapsing before any rise occurs in the values of the spoilage indices can be considered the limiting duration of storage of whole prawns at 0° C. when the prawns can be considered fresh. This period is about 5 days; it is interesting to note that the period is the same as found by Collins *et al.* (*loc. cit.*). The commencement of the steep rise in the spoilage indices after 10–12 days indicates the onset of spoilage.



Figs. 9–10. Fig. 9. Total volatile nitrogen. Fig. 10. Trimethylamine.

The observed rise in the spoilage indices in iced prawns is much lower than in the prawns held without ice. This difference is largely due to loss of the spoilage compounds through leaching in the iced prawns, though a strict comparison of the spoilage pattern of prawns held in ice and prawns

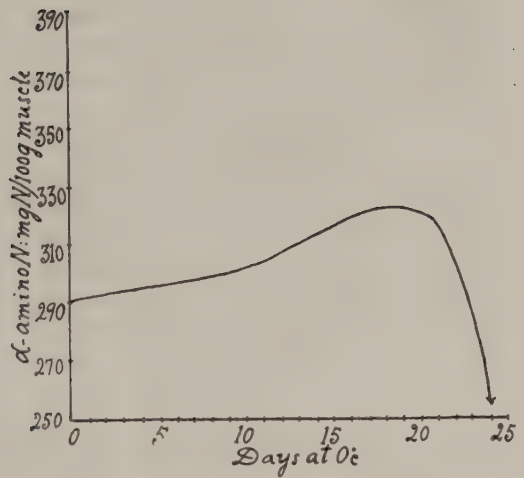


FIG. 11. Amino acid nitrogen changes in whole prawns at 0° C.

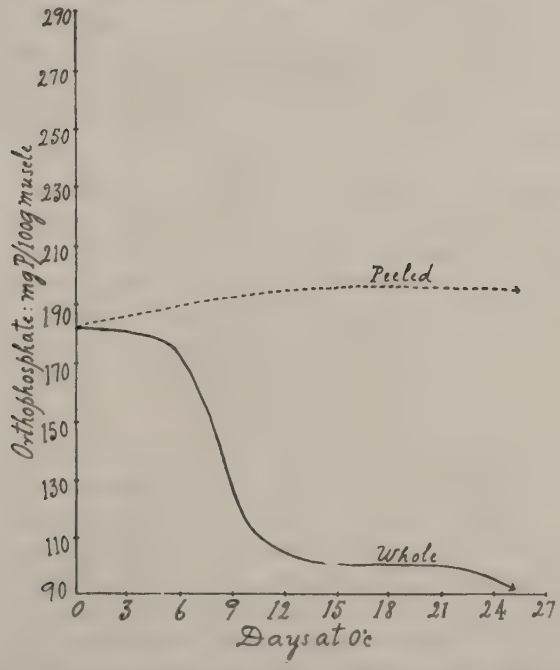


FIG. 12. Orthophosphate changes in whole and peeled prawns at 0° C.

held at 0° C. without ice, is subject to some limitations. In the case of the iced prawns the bacterial load on the external surfaces would be reduced through washing away of some of the bacteria by the melting ice. Also, in prawns held in ice the water which is also added usually in commercial handling of iced prawns, covers the surface of the prawns, thus preventing exposure of the prawns to air unlike in the prawns held without contact with ice. Melanosis incidence would therefore be expected to be more in prawns held at 0° C. without ice compared with prawns held in ice. Comparing the data and the conditions of holding the prawns it becomes obvious that the keeping quality period as seen from the objective indices would represent the minimum in the case of prawns held at 0° C. without contact with ice, and the maximum in the case of the prawns held in ice. It would be safe therefore to assume the period of 5 days indicated from the studies on prawns held without ice as the limit of storage duration at 0° C. when the prawns could be considered really fresh. The values of indices observed in prawns held without ice, though not directly applicable for assessing the quality of iced prawns, serve a valuable purpose as the reference standards.

It is noteworthy that in our present studies the bacterial count of prawns held at 0° C. decreased initially; apparently the mesophiles present in the flora of the fresh prawns do not survive long at the lower temperature; after a lag period, however, the psycrophiles present initially could be expected to multiply. This would explain the initial decrease in the bacterial count of prawns held at 0° C. and the subsequent rise.

The observed free amino-acid nitrogen concentration represents the resultant of the increase in the free amino-acids due to degradation of the protenoid substances and their decrease due to their utilisation by the bacteria, both processes presumably proceeding simultaneously. The absence of any decrease in the free amino-acid nitrogen in prawns held without ice unlike in iced prawns is in conformity with the previous observation made by Velankar and Govindan that the decrease in the free amino nitrogen is due to leaching (Velankar and Govindan, *loc. cit.*).

The curves representing the development of the spoilage indices (Figs. 7–10) indicate that peeled prawns keep better than whole prawns, headless prawns having keeping properties intermediate between the whole and peeled prawns. A possible explanation for these differences is that the cephalothorax and the exoskeleton, which is the source of surface and gut spoilage, have been removed in the case of the peeled prawns unlike in the whole prawns. Surface spoilage seems to be more significant than gut spoilage since the peeled prawns keep better than the headless prawns.

A characteristic feature of the peeled prawn spoilage is the very slow development of the VAN unlike in the whole prawns; also, in peeled prawns there is no decrease in the orthophosphate unlike in the whole prawns. The reasons for these differences are not clear at present.

Acknowledgement

The authors are grateful to Dr. S. A. Beatty, F.A.O. Processing Expert at this Station, for valuable suggestions and discussions in the course of these investigations. The authors also wish to record the assistance given by S. D. Deshpande, Technologist, in obtaining the prawns and the technical assistance given by V. K. Ramachandran, Laboratory Attender.

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LOBSTER FISHERY OFF THE SOUTH-WEST COAST OF INDIA

Anchor Hook and Trap Fisheries*

By H. Miyamoto‡ and A. T. Shariff

(*Central Institute of Fisheries Technology, Craft and Gear Wing, Cochin*)

Introduction

Lobsters as excellent food of delicacy are widely acclaimed and have a world-wide market. South Africa, Australia and Cuba rank best in the spiny lobster fisheries as can be seen by their exports to U.S.A., during 1956 (Table I).

Table I

Imports of spiny lobster to the U.S.A. 1956 (*Smith*, 1958)

Country	Form	Weight in million lb.	Value in million U.S. Dollars
South Africa ..	Tails	7·025	6·025
	Canned	1·244	1·178
Australia ..	Tails	4·688	4·617
	Canned	0·021	0·027
Cuba ..	Tails	4·303	3·402
	Canned	0·007	0·010
New Zealand ..	Tails	3·852	3·356
Mexico ..	Tails and whole	1·955	1·283
Bahamas ..	Tails and whole	1·591	0·587
Brazil ..	Tails	0·276	0·108
Spain ..	Tails	0·170	0·114
India ..	Tails	0·020	0·009
Other countries ..	Tails	0·326	0·218
Total Import ..		25·478	20·934

* Contribution No. 32 from Central Institute of Fisheries Technology (C. and G. Wing.), Cochin.

‡ F.A.O./E.T.P. Fishery Officer with the Government of India.

For the reason of its importance, many other countries are exploring this fishery on the technical point of view (Forsyth, 1946; Thomas, 1953, 1954 and 1959 and Firth and Knake, 1950). In India, lobster fishery is reported to exist on both the east and west coasts. In the Annual Report of the Central Marine Fisheries Research Station, Mandapam Camp, the year ending 31–3–1955, landings of marine prawns, shrimps and other crustaceans for the years 1950–54 have been recorded, but statistics pertaining to the lobster fishery are not available.

The survey conducted during December 1957 to February 1958 had as its objective, a study of the existing potentialities for lobsters on the south-west coast and a study of the existing craft, fishing gear, and the method of fishing with a view to extending the operations to new areas by introducing better and more efficient fishing gear.

A resume of the survey conducted is presented below:

Topography of Area under Survey

The south-west coast for the purpose of this survey covers the coastal line from Cape Comorin (Lat. 8° 05′ N, Long. 77° 33′ E) to Kolachel (Lat. 8° 10′ N, Long. 77° 15′ E) a distance of about 20 miles (Fig. 1). The whole coast is rocky and the 5 fathom line is well within about a mile from shore. From Cape Comorin, the coast bends WNW for about 14 miles to Muttam point where there is a lighthouse. From Muttam point, the coast extends NE for about 5½ miles to Kolachel. The Kolachel lighthouse is prominent on nearer approach to shore. A heavy surf persists all along the coast between Cape Comorin and Muttam point; there is also heavy surf on the coast between Muttam point to Kolachel, but the rocks lying off Kolachel form a partial breakwater within which landing is comparatively easy during a fine season.

The main fishing centres on this coast are *Cape Comorin*, *Manakudy*, *Puthanthurai*, *Pallam*, *Muttam*, *Kadiampatnam* and *Kolachel*. All these centres lie in Kanyakumari District of Madras State and are connected by good roads. Cape Comorin, the southern extremity of India, is a low sandy cape with the fishing village of Kanyakumari lying ½ mile north. Three rocks on which sea breaks, lie close SE of Cape Comorin; the ground half a mile SE and South of Cape Comorin is also rocky while the bank situated about 25 miles SW of Cape Comorin has a least depth of 30 fathoms over it.

Manakkudi is a fishing village about 4 miles west of Cape Comorin, having in its eastern side a lake which flows into the sea during rains, but during the dry season the entrance of the lake is closed.

Puthanthura is a fishing village further west of Manakudi. Pallam is another fishing village next to Puthanthura.

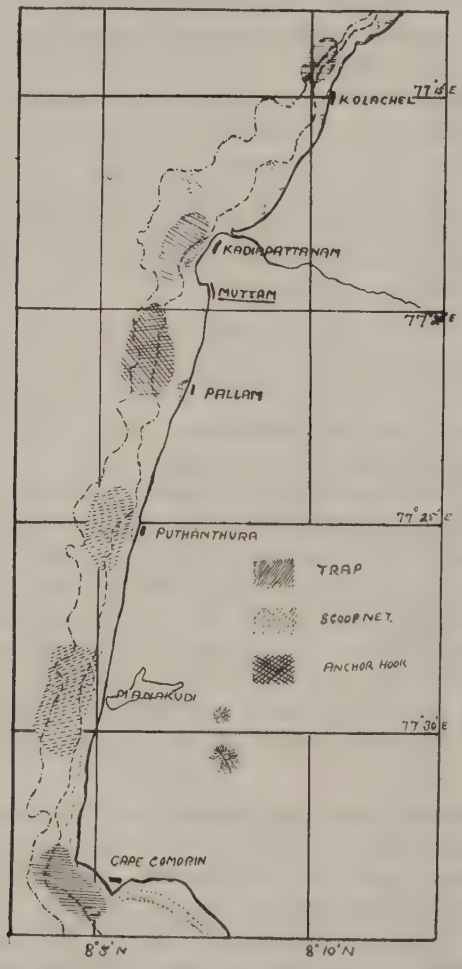

FIG. 1. Lobster fishing grounds off the south-west coast of India.

Muttam fishing village is about 114 ft. high, with steep red cliffs. A sunken rock, on which the sea breaks, lies about 3 cables SSW of lighthouse; another rock which lies one foot is situated about 1½ cables off-shore, half a mile WNW of lighthouse. The Crocodile rock about 3 miles SW of light

house has a depth of less than 6 ft. over it. Adanda an islet about $1\frac{1}{4}$ miles SW of lighthouse is difficult to identify from seaward; Kota an islet about $1\frac{1}{4}$ miles WNW of Adanda is steep on its western side. The whole village comprises of upper, lower and middle Muttams.

Kadiampatnam, about a mile NW of Muttam point, is also a pure fishing village with a highly rocky coast.

Kolachel is a port of some importance. Pulunni rock, 6 ft. high, $\frac{3}{4}$ cables SSE of Kolachel lighthouse, patna rocks about one cable WNW of Pulunni with 7 ft. of water over it, constance rocks about 2 cables NW of Pulunni with less than 7 ft. of water over it are the big rocks lying off Kolachel. Sensul and others above and below water extend to a distance of about $1\frac{3}{4}$ cables southwards to 3 cables SW of Kolachel lighthouse.

The rocky coast-line as briefed above offers plentiful supply of water well stirred for the supply of dissolved oxygen to lobsters, dark surroundings and cool even temperatures so essentially preferred by lobsters. Besides, the rocky coast being a rich ground for different kinds of bivalves, is well suited for the lobsters, offering good food.

Brief History and Present Status of the Lobster Fishery

Regarding the occurrence of different species of lobsters caught along the Indian coasts, little is known. However, diligent perusal reveal that along the Bombay coast Rai (1933) has mentioned in the account of shell fisheries of Bombay Presidency, *Panulirus ornatus* and *P. fasciatus* are being represented in the commercial lobster landings. Chopra (1939) stated that the common species occurring in the east coast is *P. polyphagus*, while *P. ornatus* is common in Bombay waters. Around Krusadai island in Gulf of Mannar, occurrence of *P. dasypus* has been indicated by Grabely (1927).

From the experiments of bottom set gill nets along the south-west coast of India, it is found that *Panulirus burgeri* is the most common and caught in large quantities along this region. Also single specimens of *P. penicillatus* and *P. polyphagus* were obtained off Quilon and Vizhingam.

Summing up, it can reasonably be said that *P. ornatus*, *P. burgin*, *P. dasypus*, *P. polyphagus* and *P. penicillatus* represent in Indian waters.

Though the exploration of the vast lobster resources and their exploitation on an intense scale had been neglected in the past, a good market for frozen lobsters in the U.S.A. in the recent years has given a new fillip to the industry.

The total production at the above-mentioned seven fishing centres contributes to a total of about 595,000 lobsters (250,000 lb.) valued at Rs. 198,000 during 1956–57.

The four kinds of fishing gears in use along the coast are traps, anchor hooks, scoop nets and hemp bottom gill nets. Traps are the oldest gear in use originally at Muttam and Kolachel. Anchor hooks and scoop nets are said to have come into existence subsequently at Muttam and Manakkudi respectively but of course in use since a very long time. Hemp bottom gill nets are of very recent origin having been introduced about three years ago at Kolachel. Due to the demand now of lobsters for frozen export, not only have the number of the above-mentioned gears increased, but they are gradually being extended and introduced to other centres also. For instance, in Cape Comorin there was no lobster fishing at all a few years ago, but now fishermen have taken up to anchor hooks since February 1956. In Manakkudi, scoop nets were originally the gear used, but now anchor books are also being employed. Since the beginning of February, anchor hook fishermen from Muttam move to Manakkudi, Puthanthura and Pallam.

During the seasons in 1956–57 and 1957–58, the number of fishermen and number of crafts engaged purely for lobster fishing are given in Table II.

TABLE II

Number of fishermen and crafts engaged in lobster fishing during 1956–57 *and* 1957–58

Name of fishing centre	Anchor hook		Scoop net		Traps		Gill net	
	F	B	F	B	F	B	F	B
Cape Comorin ..	100	100	..	..	..	..	..	..
Manakkudi ..	..	..	200	100	..	..	..	..
Puthanthura ..	..	..	..	..	..	..	..	..
Pallam ..	..	..	80	40	..	..	..	..
Muttam ..	300	300	..	..	38	19	..	..
Kadiampatnam ..	..	..	..	..	..	..	..	..
Kolachel ..	..	..	..	..	60	30	..	20

F = Number of fishermen. B = Number of catamaran.

Fishing Gear, Craft and Fishing Methods

The survey under this head have been confined to Muttam centre alone where anchor hooks and traps fishing alone exist. The constructional and operational details of anchor hooks at different centres in this coast are reported similar.

1. *Construction of the Anchor Hook*

Anchor hook consists of three parts, *i.e.*, hook, brass wire and cotton line and an accessory as shown in Fig. 2.

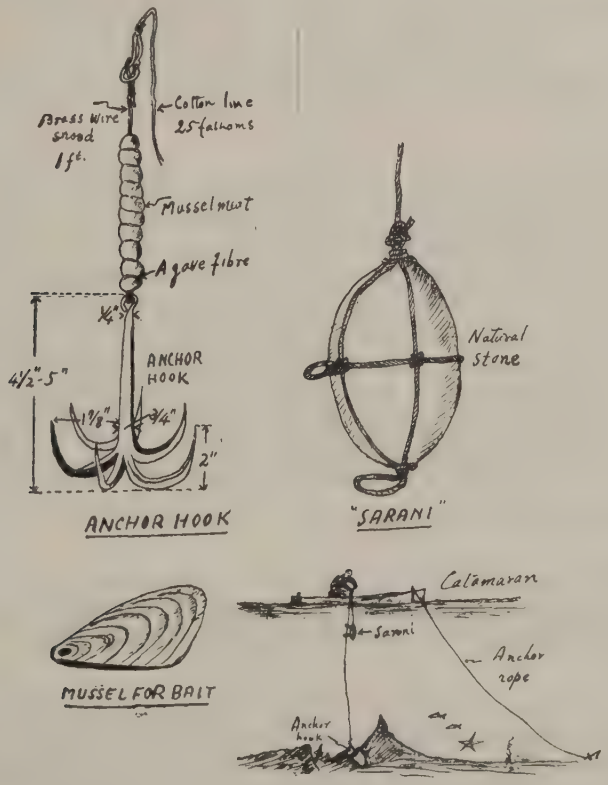

Fig. 2. Anchor hook.

(*a*) *Anchor hook*

Material.—Cast-iron.

Shape and size.—Anchor-shaped hook with 6 sharp arms from a stem, stem 4·5–5 inches long.

Maker.—There are 5 to 6 blacksmiths in the village. One blacksmith makes about 50 hooks per day.

Price.—12 annas per hook.

Period of service.—About 6 months.

Number of hooks required per fisherman.—2 (1 spare).

(*b*) *Brass wire*

Thickness of the wire.—16 gauze.

Length of wire.—About 3 fathoms. The wire is coiled and twisted to about 1 ft. in length as shown in Fig. 2.

Maker.—Sold in the fishing village.

Price.—1 anna per 3 ft.

(*c*) *Cotton line*

Material.—20S, 36 threads, 3 ply or 10S, 21 threads, 3 ply.

Length.—About 25 fathoms per hook.

Maker.—Fishermen buy yarn and twist it themselves.

Method of dyeing.—These lines are dyed with bark of " Udiyam " (Odina wodier). Suitable sizes (about $6'' \times 4''$) of the bark are cut and in wet state rolled over the cotton line, kept pressed and rubbed hard the whole length of the line for about 6 times when the line gets a dark brown colouration. They are re-dyed once in six months. If the bark of " Udiyam " is not available the fishermen use tamarind-seed skin or " Panichikka ".

Period of service.—About 6 years.

(*d*) *Accessory: "Sarani"*

The accessory consisting of a stone and a cotton line, is used for the purpose of releasing the hook when caught amidst a rock.

2. *Bait*

Mussels (*Sippi*—in Tamil) (*Mytilus* sp.) growing widely on the submerged rocks all along the coast are the only bait used. A good size mussel as a suitable bait is about $2\frac{1}{2}'' \times 1''$. The fishermen dive and remove these mussles from the submerged rocks with a special scrapper (*Ka'likku Aru'a*—in Tamil) and collect them in palmyra leaf baskets. Usually two or three days requirements are collected and a basket of these live mussels are kept submerged in sea-water near the beach and removed before the fishermen set out for fishing. In Puthanthura, Manakkudi, and Pallam where the mussel bait is

not available in plenty, fishermen procure them from Kolachel, Kadiampatnam, Kodimunai, Vaniakuddi, Kurumunai, Alkayam and Muttam at the rate of about 4 annas to 1 rupee per 100 mussels. The meat of three or four mussels is tied to the middle of the brass wire snood by very thin white fibres of Agave (*Kathalai*—in Tamil). About 75 mussels are taken on a single catamaran for a night's fishing.

3. *Fishing boat: Maram—in Tamil*

Kind of boat.—Boat catamaran.

Hull.—Local wood. (" Elavu ", " Murungai ", " Mullu elavu ", " Panju elavu ", " Sillai "—*Albizzia* spp.)

The catamaran consists of 4 logs. About 21 ft. in length, 2 ft. in width. The inner two logs are 60″ in circumference while the outer two are 80″ in circumference.

The four logs are held together in such a way that the inner two remain at a lower level keelwise, while the outer two are higher to form a trough-shaped hollow above. At each end of the logs, a transverse two horned block of wood is lashed together with the logs secured by coir ropes passed through grooves cut in the sides of the logs. The logs are kept permanently tied together. The men stand up all the time for paddling. A light bamboo yard 30 ft. in length carries the triangular tanned cotton sail over the head of a short strong spar about 7 ft. in length. While sailing, a drift plank is used between the two inner logs and a split bamboo paddle serves as rudder.

Dimensions.—About 21 ft. in length, 2 ft. in width.

Maker.—Locally made; the logs purchased from the nearby forest or estate.

Cost of catamaran.—Rs. 150 to 200 per catamaran with 4 logs.

Period of service.—Average 12 years; 20 years if well protected.

Accessory

Oar.—Bamboo, 5 to 6 ft. in length, 5 to 6 inches in width.

Sail.—Triangular sail. 24 ft. × 23 ft. × 18·5 ft. There are two kinds of sails used, one for small and another for big " Maram ".

4. *Fishing Method*

Fishing for lobsters with anchor hooks is during nights only and all catamarans sail and reach the ground just at dusk. Usually one fisherman sets out in one catamaran and very rarely another fisherman accompanies him. Reaching the ground, he anchors the catamaran, baits the line and

commences the operation. When he feels the lobster biting the bait, he pulls up the line so fiercely that the sharp arms of the anchor hook, hook the lobster on its abdomen. The operation continues the whole night and the fishermen return to shore by about 7 to 8 a.m. Some times the lobsters escape with the injury from the hook. A single fisherman catches about 20 lobsters in one night, though during the season a maximum of 50 lobsters were reported caught per head per night. As the ground is rocky, the hook often gets caught amidst the rocks and the fishermen then apply an ingenious method to release the hook. The method consists in releasing a spherical hard stone loop on to the anchor hook line, which hits the arms of the hook is bent and sometimes the snood is cut and the hook lost.

A. " *Scoop Net* " *Fishing* (*Kundam—in Tamil*)

This item will be reported separately later in this report.

B. " *Trap* " *Fishing* (*Koodu—in Tamil*)

Trap, as a gear for lobster fishing, is very common and popular in the world, but the trap which is being used along this coast is somewhat different from those of other countries in construction and operation.

1. *Construction of Trap*

The trap consists of only two parts, *i.e.*, the trap proper with a flapper and two or three stone sinkers.

(*a*) *Trap*

Material.—Date leaf-stalk stripped to thin fibres each 4 to 6 ft. long about 3 mm. broad and 2 to 3 mm. thick. 100 fibres required for one trap. Date fibres are to be purchased from villages about 22 miles away from Muttam.

Shape of trap.—See Figs. 2 to 4 in Plate VI.

Size.—Length $2\frac{1}{2}$ ft. (10 meshes).

Breadth.—2 ft. (8 meshes).

Height.—$1\frac{3}{4}$ ft. (7 meshes).

Flapper.—Upper 4 meshes, lower 3 meshes.

Maker.—The fishermen take the trap themselves. The trap consists of three parts, *viz.*, " Floor ", " Side and Roof " and " Fapper ". These parts are fabricated separately and then joined by the same fibre. The roof at the hind is not joined but looped on to the sides so that this can be easily loosened after hauling up the trap for emptying the catch.

An average trap fisherman can make 4 traps per day.

Price.—The date palm trap costs about 12 annas.

Number of traps used per catamaran.—5 to 15.

(*b*) *Stone sinker*

Material.—Granite stones.

Weight.—5 to 7 lb. per stone.

Number of stones required.—2 to 3.

(*c*) *Bait*

Kind.—Mussels similar to those used in anchor hook fishing except that the size used is mostly $1\frac{1}{2}$ to $3\frac{1}{4}$ inches in size.

Baiting.—About 300 to 500 live shells are kept on the floor of the trap and renewed usually every alternate day.

2. *Fishing Craft*

Same as described under anchor hook fishing.

3. *Fishing Method*

Fishermen engaged in this kind of fishing are good divers. Two fishermen usually set out for fishing the traps during day time. If there is more traps, a third fisherman accompanies them. About 5 to 15 traps are fixed from a catamaran according to the diving ability of the fishermen. After baiting as each trap is released in the water, one of the fishermen dives with the trap and fixes it well between the crevices and creeks of the rocky substratum, while the other fisherman on the catamaran immediately notes the position of the trap fixed, by 4 point bearing method in relation to prominent objects on the shore (*Kaniyan*—in Tamil). The high mountains and cliffs on the background, the lofty church towers, house tops on raised rocks, the lighthouse, etc., offer very good bearings for these operations. Each trap is fixed in a different position and it is said that each trap fisherman has a hereditary right for each position operated, and usually no other fisherman operates his traps in this position. The fishermen set out for hauling the traps during the early hours of the day with a good stock of bait. After searching the exact position, one of the fishermen dives with a wooden hook tied to a coir rope about 20 fathoms long to 1″ thick kept coiled on the catamaran. The diver after sighting the trap, puts on the wooden hook to the small coir rope loop specially fixed for this purpose on the front floor edge of the trap. The other fisherman on the catamaran then hauls up the coir rope, lifts the trap and empties the catch. If the catch is good, he

renews the bait and the diver after taking a few minutes rest dives again to place the trap in the same spot. They move the catamaran next, to examine the other traps and return to the shore by about 9 to 10 a.m. in time for the market.

Fishing Season and Fishing Ground

1. *Fishing Season*

(*a*) *Beginning of the season*

Cape Comorin.—In early February.

Manakkudi, Puthanthura and Pallam.—In early January.

Muttam, Kadiapatnam and Kolachel.—In middle of November.

(*b*) *Best period of the season*

January to March in all the above centres except in Cape Comorin where it is in March.

(*c*) *End of the season*

Last week of April.

(*d*) *Weather during the season*

During the first three months of the lobster fishing season, *viz.*, November to January, the whole coast from Cape Comorin to Kolachel is affected by the north-east monsoon, more adversely in Cape Comorin, which accounts for the late commencing of the fishing there. The wind continues to be more variable on the coast; land and sea breezes are well developed; the sea breeze in the afternoon is western or north-western and is normally stronger than the land breeze; sometimes north-eastern or eastern breeze may blow continuously for two or three days without any intervening sea breeze. During the rest of the period from February to April the sea remains calm with the very moderate winds. Usually the current along the coast is north-westerdly during November to January, changing over to south-easterdly from February to April. The currents during the above periods are moderate and usually weak along the coast.

2. *Fishing Ground*

(*a*) *Locality.*—Scattered submerged rocky coast-line from Cape Comorin to Kolachel, often almost opposite each fishing centre (Fig. 1).

(*b*) *Depth.*—Anchor hooks and scoop nets: 1 to 5 fathoms (within a mile).

Traps and hemp gill nets.—1 to 10 fathoms (within 2 miles).

(*c*) *Bottom nature.*—Trap fishermen operate on steep submerged granite rocks having many crevices so that the traps can be well fixed. Others prefer submerged flattened soft rocky ground.

(*d*) *Current.*—Detailed above.

(*e*) *Sea-water.*—Temperature not recorded; colour of sea-water is greenish-blue and clear.

(*f*) *Changes in the fishing ground.*—Anchor hook fishing in Cape Comorin is of recent origin having commenced in the year 1956. During the survey of Muttam coast, it was gathered that the anchor hook fishermen here who are originally fishing the area west to north-west of the Muttam lighthouse, have moved since a couple of years to the south and south-east of the lighthouse.

(*g*) *Other grounds in the vicinity.*—To be explored.

Habits of Lobsters Observed by Fishermen

The observations by fishermen, enumerated below, bear an interesting and important significance on the lobster fishery to be pursued and investigated by fishery biologists and technicians:—

1. Existence of good fishing persuade for traps in 4 to 7 fathoms depth with rocky substratum.
2. Increase in catch during new-moon period by about twice of that during full-moon period.
3. Generally better catch during rough sea days.
4. Clear sky or rain does not affect the catch.
5. Female lobsters caught throughout the fishing season bear eggs.
6. Small lobsters 1 to $1\frac{1}{2}$ inches in body length are caught during the season in traps fixed near the coast.
7. Lobsters caught during May are weaker than those caught earlier and they die within a short time after removal from the trap.
8. Lobsters continue to inhabit the same rocky grounds during the monsoon period from May, but never take to bait. They are so weak during this period that divers pick them up easily, by hand. Fishermen attribute this behaviour of lobsters to the low sea-water temperature during this period.
9. Better catch in new traps than in old ones.

10. Traps hauled up every alternate day have better catch than those hauled up every day; but the catch does not increase when traps are hauled up after two days as the bait in the traps get exhausted by then.

11. One or two lobsters usually escape from the trap every day.

Catch Variations Depending upon Lunar Periodicity

Statistics gathered, of the number of lobster traps operated in Muttam and the catch during the period from 22nd November 1957 to 23rd January 1958, are represented in Figs. 3 and 4 indicating the average catch per trap

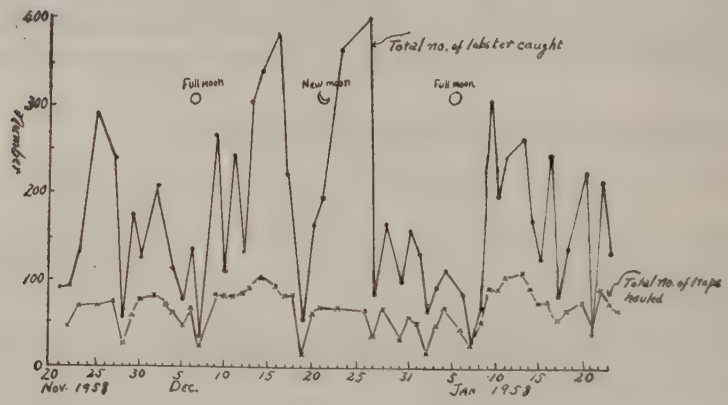

Fig. 3. Relation between the total number of lobsters caught and the total number of trap hauled per day.

each day. It will be seen from Fig. 3 that the total catch per day is approximately proportional to the number of traps hauled up.

Figure 4 explains the quantity of catch during different lunar periods and Fig. 5 details the average catch per trap per day during the first two quarters (new-moon to full-moon), during the last two quarters (full-moon and new-moon). From these, it will be seen that the catch decreases gradually during the first two quarters till the 12th day, that the catch increases gradually during the second two quarters from the 19th day, that during the intervening gap for about a week from 13th to 18th day, the catch remains extremely poor and that the average catch during the full-moon period is just about half the average catch during the new-moon period.

The above explanation conforms to the observations of the fishermen as indicated earlier, but the actual effect of moonlight on the fishery, dis-

abling the lobsters to come out of their hide-outs and seek bait, remains to be investigated.

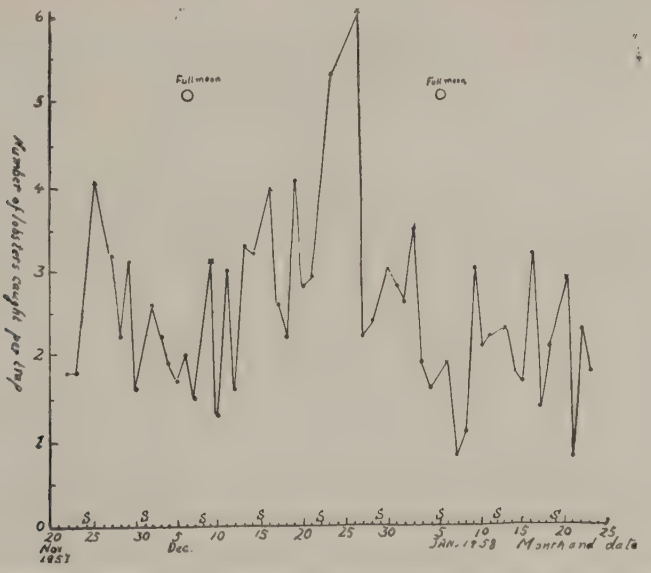

FIG. 4. Number of lobsters caught per trap during the period November 20, 1957 to January 25, 1958.

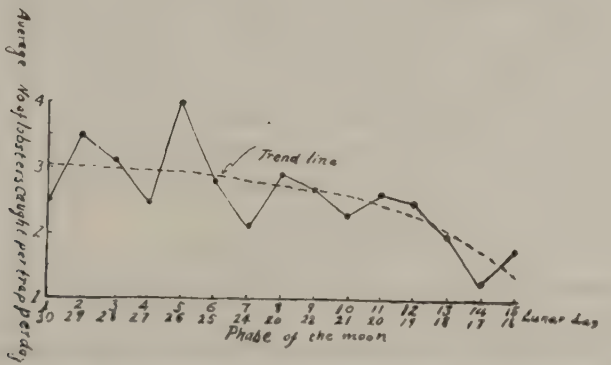

FIG. 5. Relation between the average number of lobsters caught per trap per day and the phase of the moon.

CATCH VARIATIONS DEPENDING UPON INTERVAL OF HAULS

It will be seen from Fig. 4 that the traps are not hauled up on Sundays and that the catch on Mondays following is better than on other days. The

average catch per trap on Saturdays, Mondays and Tuesdays is indicated below:

	Saturday	Sunday	Monday	Tuesday
Average catch	2·14	No fishing	3·24	1·76

From this, it may be said that an increase in the catch is perceptible for about 48 hours interval between hauls and that this conforms to the observation of the fishermen as indicated, in VI (10), but the catch variations for longer intervals between hauls remain to be investigated.

Relative Merits of the Fishery

(*a*) *Anchor Hook Fishing*.—This has the operational advantage of low investment and recurring expenditure. The catch is also rather good when compared to trap fishing, but it has some disadvantages also.

Anchor hook fishermen stay in the sea on primitive craft throughout the night tossed by the vagaries of nature. The fishing is, therefore, a very hazardous task. If this fishing is to be developed, the crafts used by these fishermen will have to be improved first.

Another disadvantage is poor price for the anchor hook lobsters compared to the trap lobsters.* As the lobsters caught are often either dead or injured by the hook, the colour of the meat blackens when frozen. Investigations on the above changes and remedial measures to preserve well the lobster meat need to be pursued by the processing technologists.

(*b*) *Trap Fishing*.—Lobster trap is a common and effective fishing gear in the world to capture lobsters and therefore this gear remains to be introduced in areas where it is not known.

But in the area under survey, the traps are being used by diver fishermen only. However good a diver may be, as his physical strength is limited, he has been found to use a maximum of 10 to 15 traps only. This obviously suggests that this fishing method should be improved so that fishermen whether divers or not can operate the gear easily in sufficient numbers. Prabhu (1954) reported about the operation of traps for catching perches in the areas

* In 1955, price of a lobster caught by trap was 0·96 to 1·28 annas and those caught by anchor hook 0·48 annas. In 1956, the price of lobster was 4–8 annas and in 1957, 4–5·5 annas for trap lobster and 3-4·5 annas for anchor hook lobster (1 Rupee = 16 annas = 0·21 U.S.$).

around Mandapam in the Gulf of Mannar and Palk Bay. About 50 traps are tied to a long rope leaving an interval of some distance. Using a canoe they are dropped to the bottom and after about 24 hours these traps are released by pulling the rope where the traps are fastened in a line. The same method will be applied in lobster trap fishery also.

The trap which is being used along the Muttam coast is very light, cheap and effective in operation.

(*c*) *Fishing craft.*—Boat-catamaran which is being used in the Muttam coast is a very primitive craft and the development of the lobster fishery in this coast line can be well attempted with an improvement of the craft first.

(*d*) *Fishing season.*—Generally, fishing season in the Muttam coast commences by about the middle of November and closes by the end of April. But, it may be possible to extend the fishing operations throughout the year except during monsoon period. A survey in detail is necessary to achieve the above objective.

(*e*) *Fishing grounds.*—As shown in Fig. 1, the fishing grounds are at present restricted just close in-shores, off each fishing centre only. This very fact suggests the need for planned attempts at extensive exploration of lobster grounds.

Summary

This paper deals in detail the anchor hook and trap fisheries for catching lobsters off the south-west coast of India. Descriptions regarding the data collected, on the number of traps operated and the number of lobsters caught and the relation between the different phases of moon and the catches, are described. Another article quoted in the paper is the explanation upon the catch variations of lobster depending on the interval of hauls of traps and the relative merits of the fisheries.

Acknowledgements

We are thankful to M/s. Southern Fisheries Corporation and the fishermen in Muttam for their co-operation in the survey of fisheries and the collection of data. Our sincere thanks are due to Dr. N. K. Panikkar, Fisheries Development Adviser with the Government of India, for going through the manuscript and offering his valuable suggestions.

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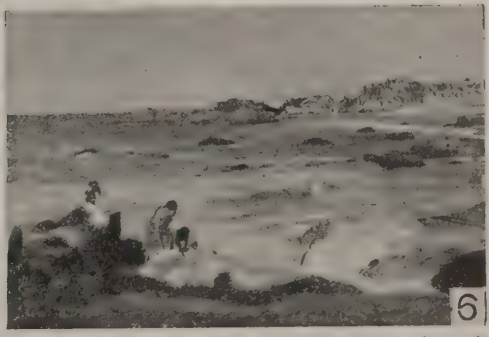

FIGS. 1–6. Lobster Industry at Muttam Point. Fig. 1. Anchor hook. Fig. 2. Lobster trap (top view). Fig. 3. Lobster trap (side view). Fig. 4. Diver fishermen with their trap. Fig. 5. Pre-process of Lobster for freezing. Fig. 6. A view of Muttam Point.

A FURTHER ACCOUNT OF THE ROCK-LOBSTER FISHING EXPERIMENTS WITH BOTTOM SET GILL NETS

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Introduction

In their preliminary account, the authors (1960) presented the results of the experimental rock-lobster fishing operations conducted during 1958–59 along the south-west coast of India with a new design of bottom set gill nets. With a view to studying in detail the working of this lobster fishing gear, a series of further tests were made at different fishing grounds extending from Quilon to Muttom along the south-west coast of India during 1959–60 and the results are presented in this paper.

Fishing was conducted under varying conditions and the day-to-day catch of lobsters was recorded. Details of the catch data in relation to depth of grounds fished, nature of the bottom and the set position of the fishing gear are analysed at length and are presented in the form of exhaustive tabular statements. The length and weight range for the lobsters caught in this new fishing gear have also been analysed and recorded.

Fishing Gear and Boat Used

The design details of the bottom set gill nets employed during the present investigations for the capture of rock-lobsters were basically similar to those operated on a former occasion. However, a few modifications were found essential and they were made as detailed below:

The depth of the net was reduced from 15 to 10 meshes. In some of the nets the mesh size was increased from 6 to $6\frac{1}{2}''$ (15·24–16·71 cm.) without altering the total area of webbing, keeping 230 meshes in length and 9 meshes in depth. Twenty numbers of light wooden floats made of "Elavu" (*Bombax malabaricum*) were attached to the head rope, keeping the buoyancy at 0·91 kg. The disc-shaped cement sinkers used on former occasions were found to entangle in the webbings and as such spindle-shaped lead sinkers each weighing 45·4 gm. were used. The total weight thus attached to the foot rope was 1·36 kg. For the net fabric, Nylon and Terylene of size No. 6 were used.

The head and foot ropes were of Nylon of 3 mm. and 5 mm. diameter respectively.

A 9·12 m. (30 ft.) decked fishing boat fitted with a 30 B.H.P. Semi-Diesel Engine (*Fishtech No.* 1 of CFTRS) and a small motorized skiff were used for conducting the fishing operations. Deshpande (1960) in his account of the fishing experiments conducted with a 10′ beam trawl net, has given detailed specifications of Fishtech No. 1. In the absence of deck machineries on board Fishtech No. 1, the manual handling of the fishing gear was resorted to.

Fishing Grounds Investigated

Quilon, Varkala, Vizhingam and Colachel-Muttam were the four bases from where day-to-day fishing cruises were undertaken and several fishing operations were conducted at different grounds. The topography of each centre is given as under:—

1. *Quilon* (Fig. 1).—Quilon City (8° 53–54′ N. Latitude and 76° 35′–36′ E. Longitude) situated on the coast is an important fishing centre.

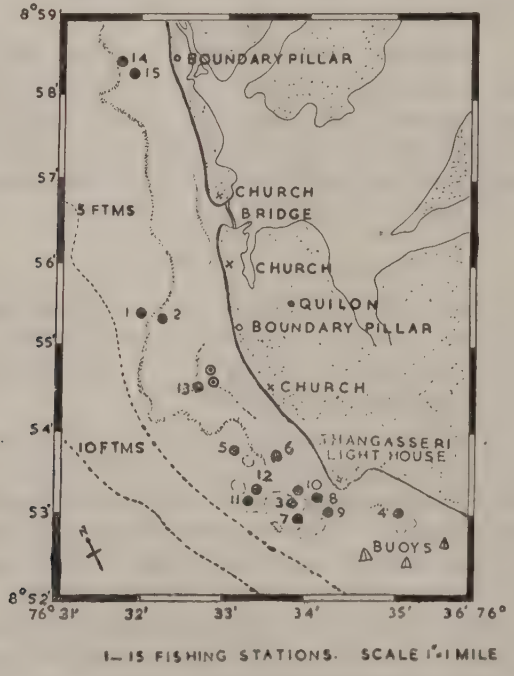

Fig. 1. Showing the fishing grounds and stations fished off Quilon.

The coast is steep and sandy as far north-westward as ' Tangasserry cove ' about $2\frac{3}{4}$ cables north eastward of ' Tangasserry point '. A lighthouse is built at ' Tangasserry point ' where the coast is rocky. The surf is heavy and due to rocky outcrops navigation is hazardous and landing difficult. Conical marking buoys are moored in sea lying opposite the ' Tangasserry point ' and these denote the extremities of a number of detached rocky shoals. ' Tangasserry reef ' consists of foul grounds and shoal water extending about a mile south-westward and $1\frac{1}{2}$ miles westward of ' Tangasserry point ' and the sea breaks over the reef at all times. Quilon is connected with backwaters and canals on both south and northwards. ' Neendakara Azhi ' about $3\frac{3}{4}$ miles north north-westwards of ' Tangasserry point' is the outlet of ' Astamudi Kayal ' and this is traversed by a conspicuous bridge. The channel leading to the sea is very narrow and limited (*West Coast of India Pilot*, 1950).

The local fishermen have been fishing lobsters at this centre since 1958 with old hemp nets set as bottom gill nets. The fishing season here extends from September to beginning of November. However, experimental fishing for lobsters with the new gear was conducted off this centre for 8 days during December, 1959 and January, 1960 covering 15 selected Stations, at depths ranging from 4·5 to 8·5 m. within a reach of $1\frac{1}{2}$ to 2 miles (2·4–3·2 km.) from the shore. The details of the fishing Stations are given in the enclosed fishing log (Appendix I). During the period of our present investigations, the local fishermen were not engaged in lobster fishing.

2. *Varkala* (Fig. 2).—Varkala, a small town about 13 miles (20·8 km.) south of Quilon, lies at Latitude 8° 44′ N. and Longitude 76° 41′ E. The fishing village of this centre is connected by a feeder road to the trunk road. The coast is partly sandy and partly rocky, which at many a place presents precipitous formations, popularly called ' Varkala cliffs '. Generally heavy surf breaks on the coast which makes landing difficult.

Fishing could be conducted only for a day here at 2 Stations having depths of 5·0 to 8·25 metres and about a mile (1·6 km.) away from the shore. Appendix II shows the details of the Stations fished.

3. *Vizhingam* (Fig. 3).—Vizhingam (Latitude 8° 23′–24′ N. and Longitude 76° 59′–77′ E.), an important fishing village, is situated on the shore about 9 miles (14·4 km.) from Trivandrum, the capital city of Kerala. The coast is steep and rocky at most of the places especially on both sides of Vizhingam Bay, which itself is protected by two extensive rocky projections, on either side. The sea, though calm during fine weather, becomes rough during monsoon with heavy surf.

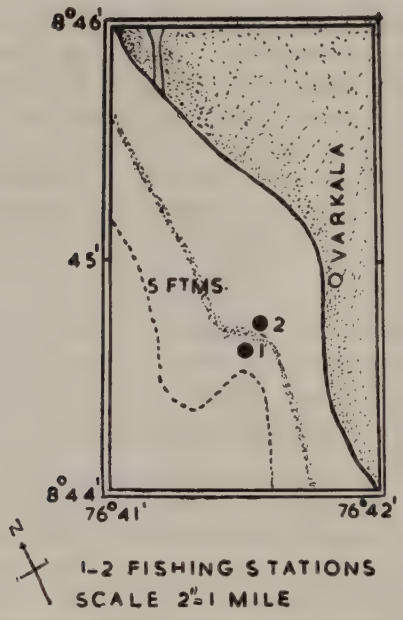

FIG. 2. Showing the fishing grounds and stations fished off Varkala.

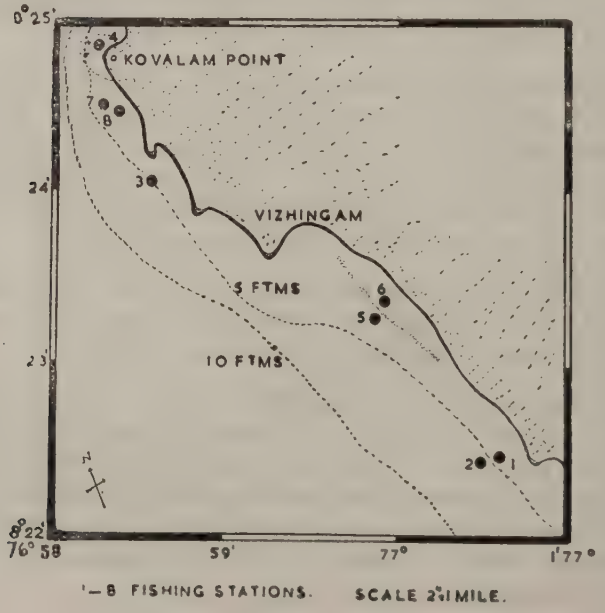

FIG. 3. Showing the fishing grounds and stations fished off Vizhingam.

At this centre fishing experiments were conducted for 5 days during December, 1959, at 8 different selected Stations having depths of 4·5 to 11·0 metres and within ½ a mile (0·8 km.) reach from the shore. The details for each of the fishing Stations are indicated in the enclosed fishing log (Appendix III).

4. *Colachel–Muttam* (Fig. 4).—Colachel (Latitude 8° 10′ N. and Longitude 77° 14′ E.) is a small port connected by road to Nagercoil and also with a

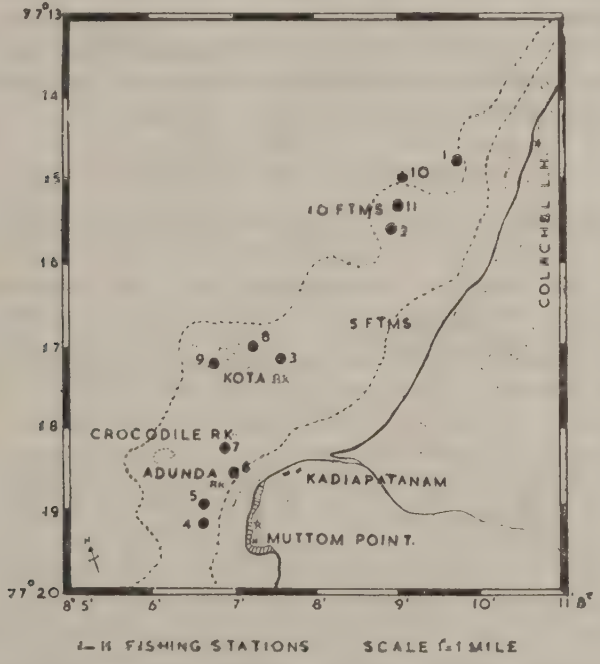

FIG. 4. Showing the fishing grounds and stations fished off Colachel-Muttam.

kutcha coastal road to Muttam. From Colachel the coast trends in a generally north-westerly direction for about 26 miles (41·6 km.) to Trivandrum. A brief description of this centre has been given by the authors in their previous communication (*op. cit.*, 1960). A number of submerged as well as exposed rocks are scattered in the sea off this coast. The situations of the most prominent rocks of this area were indicated by Miyamoto and Shariff (1958) in their earlier report. Heavy surf breaks on the coast, but these numerous rocks form a partial breakwater within which landing is comparatively safe.

In Colachel-Muttam area, the fishing investigations were carried out for 6 days during January, 1960. Fishing was conducted at 11 Stations having varying depths from 7·5 to 24·0 metres and within 3 to 3½ miles (4·8–5·6 km.) from the shore. The fishing details for each Station are given in the accompanying fishing log (Appendix IV).

Fishing Operations

The present fishing cruise, started during the beginning of December, 1959, continued up to the end of January, 1960, during which period 20 days of actual fishing was conducted at different centres, covering about 36 selected Stations in all. At each of the Stations, one unit consisting of 15 pieces of net was set. Generally the nets were set in the evening and hauled up next early morning, thus keeping them to fish overnight.

Method of Setting and Hauling

Setting of nets was done from the stern and they were retrieved from the port or starboard side of the boat depending on the direction of wind and speed of the current. For purposes of easy and methodical way of setting, the nets were arranged on the aft deck of the boat as detailed below:

The two extreme ends of head and foot ropes of the first piece of net were further extended by attaching side ropes of sisal of ¼″ (0·63 cm.) diameter to a length of 3 fathoms (5·2 m.). The end of the side rope of the bottom line was fastened at a point on the buoy rope, where the stone sinker was tied securely and to the other free end of buoy rope were attached buoys and marking flags. The buoy rope is made of coir of ¾″ (1·88 cm.) in diameter and 10 to 15 fathoms (18–27 m.) in length. Then the end of the side rope on the head line was looped to the buoy rope at a distance equal to the depth of the net from the bottom end of buoy rope. The required number of pieces of netting were joined end to end at both the head and foot ropes, while keeping the nets across the deck in regularly arranged folds as floats and float-line to the port side and lead-line to the starboard side. After thus arranging all the 15 pieces, to the free end of the last piece of net similar side ropes were fastened for attaching stone sinker, buoy rope and buoy with flag marks as was done before for the first piece of net. At places where two pieces are joined in a set 2 to 3 cement sinkers weighing ½ lb. (0·22 kg.) were tied. One more set of net was also got ready in a similar fashion. On reaching the prospective fishing ground, speed of the boat was reduced, necessary soundings for depth as well as the nature of bottom and current were checked and recorded. Maintaining a steady course and slow speed, shooting operations

started first with releasing of the flag mark with buoy and anchor, followed by the netting proper. Care was taken not to allow the net to foul. After releasing all the pieces, the other buoy rope with flag and anchor were thrown overboard. The opposite forces acting on the float-line and the lead-line due to the attachment of floats and sinkers respectively work in such a way as to sink the net to the desired depth besides keeping the entire fishing gear erect. After taking the necessary bearings of the fishing ground the boat returned to the base. The nets were left at the grounds to fish overnight.

Early next morning, the fishing grounds were visited and the hauling of the gear was done following the same procedure (*viz.*) picking up the flag and buoy, its ropes with anchor, followed by the net and other components. The nets were retrieved either from the port side or starboard side of the boat depending on the prevailing wind and current conditions. As the nets were hauled, catches were removed. It was also observed that on an average 11·4 and 16·5 minutes were taken for setting and hauling of one set of nets respectively with 6 men on board to assist in the operation.

Results

The results and findings of the experimental fishing operations are presented in the attached Tables I to X.

Discussion

Catches.—Panulirus ornatus and *P. polyphagus* are the common species of lobsters found in Bombay waters of the west coast of India (Rai, 1933). The commercial landings along the south-west coast of India are mostly made up of *P. dasypus* and *P. burgeri* (It is doubtful whether both are of the same species). During the period of the present investigations at different centres, the main species in the bulk of the catches was *P. burgeri.* It is interesting to record that at Vizhingam, a single specimen of *P. polyphagus* measuring 36 cm. in length and weighing 1·36 kg. was caught at a depth of 10 metres where the bottom was sandy. Similarly off Quilon a solitary specimen of *P. penicillatus* of length 36 cm. and weight 1·13 kg. was caught at a depth of 5 to 6 m. where the bottom was sandy with few sea-weeds scattered here and there.

The day-to-day catch details of the bottom set gill net at the different fishing centres are given separately in the attached Tables I, II, III and IV.

It will be seen from the Tables I to IV, that 549 pieces of netting in all as 244 at Quilon, 30 at Varkala, 110 at Vizhingam and 165 at Colachel-Muttam were used. During the entire period of the present experimental

TABLE I

Catch details of the bottom set gill net fishing operations at the different stations off Quilon, during December 1959 and January 1960

Dates of operation	Fishing ground		No. of pieces set	Catch details				Total weight in kg.
				Lobsters		Fishes		
	Station	Depth in metres		No.	Weight in kg.	No.	Weight in kg.	
9–10/12–59	1	6·5	15	1	1·13	3	6·58	7·71
9–10/12–59	2	4·5–6·5	15	2	1·36	1	4·08	5·44
10–11/12–59	3	5·5–6·5	15	9	5·90	15	17·69	23·59
Do.	4	6·5–7·5	15	4	2·73	5	2·49	5·22
11–12/12–59	5	5·5–6·5	15	2	0·91	2	2·49	3·40
Do.	6	4·5–6·0	15	66	34·93	9	8·84	43·77
19–20/1–60	7	5·5–6·5	15	1	1·13	7	11·8	12·93*
Do.	8	4·5–5·5	15	22	10·43	..	..	10·43
20–21/1–60	9	5·5–6·5	20	3	2·27	3	4·08	6·35
Do.	10	6·5–7·5	15	23	17·69	4	2·04	19·73
21–22/1–60	11	4·5–8·5	15	46	30·39	11	22·00	52·39*
Do.	12	4·5–7·0	20	38	19·96	15	34·47	54·43*
24–25/1–60	13	5·0–6·0	18	18	7·83	9	27·67	35·50*
25–26/1–60	14	5·5	20	..	..	2	18·60	18·60
25–26/1–60	15	4·5–5·0	16	2	1·82	3	12·24	14·06
Total ..	..	..	244	237	138·48	89	175·07	313·55
Catch per day in kg. ..	..	..		29·63	17·31	11·12	21·88	39·19
Catch per piece in kg. ..	..	..		0·97	0·57	0·36	0·72	1·29

Note.—Fishes mainly include sharks, perches and cat-fishes.

* Includes weight of turtles caught approximating to 33·11 kg.

TABLE II

Catch details of bottom set gill net fishing operations at the different stations off Varkala during December 1959

Dates of operation	Fishing ground		No. of pieces set	Catch details				Total weight in kg.
	Station	Depth in metres		Lobsters		Fishes		
				No.	Weight in kg.	No.	Weight in kg.	
17–18/1–60 ..	1	5·5	15	2	1·59	22	20·86	22·45
Do. ..	2	5·0–8·25	15	..	..	20	7·26	7·26
Total ..	..	..	30	2	1·59	42	28·12	29·71
Catch per day in kg. ..	..	..	2	1·59	42	28·12	29·71	
Catch per piece in kg. ..	..	..	0·07	0·05	1·40	0·94	0·99	

Note.—Fishes include small rays only.

fishing operations, 295 lobsters weighing 160·08 kg. and miscellaneous fishes weighing 484·49 kg. were caught.

At Quilon, maximum number of lobsters (*viz.*) 237 weighing 138·48 kg. were obtained for 8 days fishing in addition to fishes weighing 175·07 kg. (Table I). It was found that at this centre the catch per day worked out to be 29·63 lobsters, while the weight of lobsters per piece was 0·59 kg., which were the highest, compared to other centres, in spite of a lean season for lobsters. Fishermen of this area had suspended lobster fishing operations a month ago presuming that the season was over.

For a day's operation off Varkala only 2 lobsters (1·59 kg.) and fishes (28·12 kg.) were caught (Table II). Further fishing could not be continued due to unavoidable reasons.

The five days' fishing at Vizhingam, yielded a total of 18 lobsters of weight 12·70 kg. and fishes of weight 117·79 kg. (Table III). On an average 3·6 lobsters per day and 0·12 kg. per piece were obtained at this centre while the rate of catch per day was 3·8 lobsters for the set nets of hemp operated by the local fishermen during the same period. The fishing grounds here are

TABLE III

Catch details of bottom set gill net fishing operations at different stations off Vizhingam during December 1959

Dates of operation	Fishing ground		No. of pieces set	Catch details				Total weight in kg.
	Station	Depth in metres		Lobsters		Fishes		
				No.	Weight in kg.	No.	Weight in kg.	
16–17/12–59 ..	1	10·0–11·0	15	1	1·36	9	17·24	18·60
17–18/12–59 ..	2	9·0–10·0	15	..	..	78	47·61	47·61
18–19/12–59 ..	3	10·0	15	2	0·91	21	21·77	22·68
Do. ..	4	6·5–7·5	15	..	..	11	6·80	6·80
19–20/12–59 ..	5	5·5–8·5	15	8	6·35	2	1·82	8·17
Do. ..	6	4·5–5·0	15	7	4·08	3	5·67	9·75
22–23/12–59 ..	7	5·5–7·5	10	..	..	2	2·27	2·27
Do. ..	8	8·5–9·0	10	..	..	15	14·61	14·61
Total	..	..	110	18	12·70	141	117·79	130·49
Catch per day in kg. ..	..	..	..	3·6	2·54	28·2	23·56	26·10
Catch per piece in kg. ..	..	..	..	0·16	0·12	1·28	1·07	1·19

Note.—Fishes include rays, sharks, Jew fish, perches and cat-fish.

very limited and are restricted to the few rocky areas. Only these limited resources are intensely fished by the local fishermen. Off Colachel-Muttam area, a total of 38 lobsters weighing 15·31 kg. and 163·51 kg. of fish were caught for a period of 6 days' fishing (Table IV). The catch per day worked out to be 6·33 lobsters while the average weight of lobsters per piece was 0·09 kg. which is more or less similar to last year's observations (*op. cit.*, 1960). Further, it has been observed that during the same period catch of lobsters by the local fishermen using traps and anchor hooks was comparatively poor.

TABLE IV

Catch details of bottom set gill net fishing operations at different stations off Colachel–Muttam during January 1960

Dates of operation	Fishing ground		No. of pieces set	Catch details					Total weight in kg.
	Station	Depth in metres		Lobsters			Fishes		
				No.	Weight in kg.		No.	Weight in kg.	
7–8/1–60	.. 1	10·0–12·0	15	5	1·59		36	40·60	42·19
Do.	.. 2	11·0–14·0	15	6	1·82		3	2·38	4·20
8–9/1–60	.. 3	17·5–18·5	15	..	..		10	13·95	13·95
9–10/1–60	.. 4	9·0	15	9	4·76		14	14·08	18·84
Do.	.. 5	9·5–13·0	15	16	6·46		38	58·52	64·98
10–12/1–60	.. 6	7·5–10·0	15	2	0·68		5	10·66	11·34
Do.	.. 7	11·0–14·0	15	..	..		3	2·72	2·72
12–13/1–60	.. 8	15·5–24·0	15	..	..		4	7·45	7·45
Do.	.. 9	15·0–20·0	15	..	..		4	4·08	4·08
15–16/1–60	.. 10	13·0–15·0	15	..	..		10	9·07	9·07
Do.	.. 11	13·0–14·0	15	..	..		..	..	..
Total	.. ..	..	165	38	15·31		127	163·51	178·82
Catch per day in kg.	.. ..	..	..	6·33	2·55		21·17	27·25	29·80
Catch per piece in kg.	.. ..	..	..	0·23	0·09		0·77	0·99	1·08

Note.—Fishes include sharks, rays, perches, cat-fish and moon-fish.

Table V indicates the catch of lobsters as well as fishes per unit area of webbing, the unit area being taken as 9·281 sq. m. (100 sq. ft.). The catch per unit area of webbing was worked out using the formula presented in our previous communication (1960, *op. cit.*). In the last column of Table V, the number of lobsters obtained per piece of netting at each of the centres are given for easy comparison. It is evident that the catch of lobsters at

TABLE V

Catch in kilograms per unit area of the bottom set gill net at different centres*

Fishing centre	Catch per 9·281 sq.m. (100 sq.ft.) of webbing			Catch in number of lobsters per piece of netting
	Lobsters in kg.	Fishes in kg.	Total in kg.	
Quilon ..	0·2014	0·2546	0·4560	0·97
Varkala ..	0·0188	0·3367	0·3555	0·07
Vizhingam ..	0·0432	0·4112	0·4544	0·16
Colachal-Muttam ..	0·0329	0·3517	0·3846	0·23

* Unit Area = 9·281 sq.m. (100 sq. ft.) of webbing.

Quilon was the highest when compared to other centres, being 0·97 kg. per piece and 0·2014 kg. per unit area of netting. This may probably be due to the fact that lobster fishery in these areas has started only a couple of years back and the rich and extensive grounds for lobsters are exploited by few fishermen only at present. Contrary to this the catch of fish for similar unit of webbing at this centre is the lowest indicating the possible effect of this new gear for the exclusive capture of lobsters. Lowest catch was noticed at Varkala. The catch per unit area was more or less identical with the other two centres, which were nearly one-fifth and one-sixth of Quilon. In the case of fish catch, Vizhingam recorded the highest per unit area of webbing. At Colachel–Muttam area it has been observed that the number of lobsters captured per piece during the present season was 0·23 as against 0·28 during 1958–59 (*op. cit.*, 1960), but catch of lobsters in terms of weight per unit area of webbing was 0·0329 as against 0·0250 kg. This may possibly be due to the fact that the sizes of lobsters caught in the gear were large and the grounds fished are different from that exploited by the local fishermen.

EXTENT OF FISHING GROUNDS

From the attempts so far made to assess the probable extent of lobster fishing grounds of the four centres fished, it has been observed that the area off Quilon and Colachel–Muttam were comparatively extensive whereas the grounds off Varkala and Vizhingam were very restricted and narrow.

The extent in the case of these latter two centres was limited and within $\frac{1}{4}$ mile from the shore. The present evidences indicate the probable existence of lobster fishing grounds to an extent of about 6 sq. miles off Quilon, 1 sq. mile each both at Varkala and Vizhingam and 11 sq. miles off Colachel–Muttam centres.

Size and Weight of Lobsters

The total length and weight of all lobsters caught were measured. The length frequency and weight frequency distribution of these measurements are given in Tables VI and VII. It can be seen from Table VI that majority

Table VI

Length frequency table for lobsters caught at different centres

Size in cm.	Name of centre				Total	Average weight of each in gm. in this size-group
	Quilon	Varkala	Vizhingam	Colachel-Muttam		
12–17	5	..	..	3	8	225
17–22	34	1	4	11	50	382
22–27	114	1	8	21	144	515
27–32	73	..	5	3	81	790
32–37	11	..	1	..	12	1,042

Table VII

Weight frequency table for lobsters caught at different centres

Weight in kg.	Name of the centre				Total
	Quilon	Varkala	Vizhingam	Colachel–Muttam	
0–0·4	50	..	3	10	63
0·4–0·8	138	1	9	25	173
0·8–1·2	48	1	5	3	57
1·2–1·6	1	..	1	..	2

of lobsters (about 49%) in the total catch fall under the size range of 22–27 cm. About 93% of the catch have their lengths confined within the range of 17–32 cm. It is evident that the gear used during the present investigations caught only lobsters of fairly large size letting the small ones to escape.

As can be seen from Table VII about 58·5% of the lobsters in the entire catch fall under the weight group of 0·4–0·8 kg. The average weight of lobster in each of the size-groups was shown in the last column of Table VI and it is found that each individual in the majority size weigh on an average 515 gm. The modal size and weight of lobsters at all the four centres were 25 cm. and 0·6 kg. respectively.

Catch in Relation to Depth and Nature of Bottom

The number of lobsters caught at different depth limits at the fishing grounds has been shown in Table VIII. Regarding the availability of lobsters with respect to depth, majority (about 86%) were caught from depths ranging from 3 to 7 m. At Quilon and Vizhingam centres they were found

Table VIII

Number of lobsters caught at different depths at different centres

Depth in metres	Number of lobsters caught at				Total
	Quilon	Varkala	Vizhingam	Colachel–Muttam	
3–5	92	†	15	†	107
5–7	145	2	*	†	147
7–9	*	*	*	2	2
9–11	*	†	3	9	12
11–13	†	†	*	27	27
13–15	†	†	†	*	*
15–18	†	†	†	*	*
18–21	†	†	†	*	*
21–24	†	†	†	*	*

* Fished, No catch. † Not fished.

to inhabit the shallower regions as evidenced by data presented in Table VIII. Off Colachel–Muttam area, though the majority came from 9 to 13 m. depth range, the gear was not purposely tried in inshore waters to avoid interference with the local fishing. However, when the gear was operated at deeper waters up to 24 m. depth no lobsters were caught in the nets. To some extent these observations indicate their availability in shallow regions along the coast rather than the deeper waters beyond 15 m. However, this fact requires further confirmation by large-scale experiments.

Table IX shows the number of lobsters caught on various types of bottom, *viz.*, rocky, rock and sand combination and sandy. Regarding the preferential habits shown by lobsters to environmental conditions especially towards the nature of bottom where they generally prowl, it has been observed that they prefer rocky nature of bottom rather than the other types mentioned (*vide* Table IX). Two isolated specimens belonging to two different species were caught on sandy bottom and this has only to be considered as casual straying individuals.

TABLE IX

Number of lobsters caught in relation to the number of pieces of netting set on different types of bottom

Nature of bottom	Rocky	Combination of rock and sand	Sandy
Number of pieces of netting set in each	373	126	50
Number of lobsters caught ..	279	14	2

CATCH IN RELATION TO THE POSITION OF NETS SET

With a view to observing the relative efficiency of the working of the nets set at different angles to the shore-line, an attempt was made by setting the nets parallel and as well as perpendicular to the shore-line at all the four centres. As seen in Table X, it is strikingly interesting to note that nets set parallel to the shore-line yielded more number of lobsters than the nets set perpendicular to the shore (about 46% as against 16%). It may be said that in all probability there exists a pattern in the normal movements of the lobsters towards the shore-line particularly during the period of the present

TABLE X

Number of lobsters caught in relation to the position of the nets set

Fishing centre	Number of pieces set parallel to the shore-line	Number of lobsters caught	Number of pieces set perpendicular to the shore-line	Number of lobsters caught
Quilon ..	229	235	15	2
Varkala ..	30	2	..	..
Vizhingam ..	95	17	15	1
Colachal–Muttam	30	14	135	24
Total ..	384	268	165	27

investigations. However, this observation has to be supported by further evidences.

SUMMARY

In continuation of the preliminary lobster fishing experiments with newly designed bottom set gill nets conducted during 1958–59, further fishing experiments were undertaken during the season of 1959–60 covering different fishing grounds off Quilon, Varkala, Vizhingam and Muttam-Colachel centres along the South-West Coast of India. The complete data collected and observations made during the current investigations are presented exhaustively in this paper.

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APPEN

Fishing Log

Fishing Centre: Off Quilon.

Stations fished	1	2	3	4	5	6	7
Dates of operation	9–10/ 12–59	9–10/ 12–59	10–11/ 12–59	10–11/ 12–59	11–12/ 12–59	11–12/ 12–59	19–20/ 1–60
Position Longitude East	76° 32′	76° 32–33′	76° 33–34′	76° 35′	76° 33–34′	76° 33–34′	76° 34′
Latitude North	8° 55–56′	8 55–56′	8° 53–54′	8° 53′	8° 53–54′	8° 53–54′	8° 53′
Depth in metres	6·5	4·5– 6·5	5·5– 6·5	6·5– 7·5	5·5– 7·5	4·5– 6·0	5·5– 6·5
Nature of bottom	Rocky	Rocky	Rocky	Rocky and sandy	Rocky and sandy	Rocky	Sandy
Time of setting (hrs.)	17·20 to 17·40	18·00 to 18·20	15·30 to 15·45	15·55 to 16·10	15·30 to 15·40	15·50 to 16·00	16·00 to 16·10
Time of hauling (hrs.)	6·15 to 6·35	6·40 to 7·00	6·20 to 6·31	6·40 to 7·00	6·20 to 6·35	6·40 to 6·55	7·05 to 7·15
Condition of weather	Fair	Fair	Fair	Fair	Fair	Fair	Fair
Condition of sea	Calm	Calm	Calm	Calm	Calm	Calm	Calm
Condition of current	Weak	Weak	Weak	Weak	Weak	Weak	Weak
Total No. of lobsters caught	1	2	9	4	2	66	1
Weight of entire catch in kg.	7·71	5·44	23·59	5·22	3·40	43·77	12·98

DIX I

Sheet

Fishing Gear used: Bottom set gill nets.

8	9	10	11	12	13	14	15
19–20/ 1–60	20–21/ 1–60	20–21/ 1–60	21–22/ 1–60	21–22/ 1–60	24–25/ 1–60	25–26/ 1–60	25–26/ 1–60
76° 34–35′	76° 34–35′	76° 34′	76° 33–34′	76° 33–34′	76° 32–33′	76° 31–32′	76° 32′
8° 53–54′	8° 53′	8° 53–54′	8° 53–54′	8° 53–54′	8° 54–55′	8° 58–59′	8° 58–59′
4·5– 5·5	5·5– 6·5	6·5– 7·5	4·5– 8·0	4·5– 7·0	5–6	5·5	4·5– 5·0
Rocky	Rocky and Sandy	Rocky	Rocky	Rocky	Rocky	Sandy	Rocky and Sandy
15·40 to 15·50	16·00 to 16·10	16·20 to 16·30	16·15 to 16·36	16·40 to 16·50	15·05 to 15·15	16·20 to 16·30	16·30 to 16·40
7·30 to 7·40	6·35 to 6·55	7·00 to 7·20	6·45 to 7·10	7·15 to 7·35	6·45 to 7·10	7·20 to 7·35	7·45 to 8·00
Fair	Fair	Fair	Fair	Fair	Fair	Fair	Fair
Calm	Calm	Calm	Calm	Slightly rough	Slightly rough	Calm	Calm
Weak	Weak	Weak	Weak	Weak	Weak	Slightly strong	Slightly strong
22	3	23	46	38	18	..	2
10·43	6·35	19·73	52·39	54·43	35·50	18·60	14·00

Remarks.—Nets set in the previous evening are hauled in the next morning.

APPENDIX II

Fishing Log Sheet

Fishing Centre: Off Varkala. Fishing Gear used: Bottom set gill net.

Station fished		1	2
Date of operation	..	17–18/1–60	17–18/1–60
Position:			
Longitude (East)	..	76° 41–42′	76° 41–42′
Latitude (North)	..	8° 44–45′	8° 44–45′
Depth in metres	..	5·5	5–8·25
Nature of bottom	..	Sandy and Rocky	Sandy and Rocky
Time of setting	..	16·20–16·30 hr.	16·40–16·50 hr.
Time of hauling	..	6·15–6·35 hr.	6·45–6·55 hr.
Condition of weather	..	Fair	Fair
Condition of sea	..	Calm	Calm
Condition of current	..	Weak	Weak
Total number of lobsters caught	..	2	..
Weight of entire catch in kg.	..	22·45	7·26

Remarks.—Nets set in the previous evening are hauled in the next morning.

APPENDIX III

Fishing Log Sheet

Fishing Centre: Off Vizhingam. Fishing gear used: Bottom set gill nets.

Stations fished	1	2	3	4	5	6	7	8
Dates of operation ..	16-17/12-59	17-18/12-59	18-19/12-59	18-19/12-59	19-20/12-59	19-20/12-59	22-23/12-59	22-23/12-59
Position: Latitude (East) ..	77°-77° 1′	77°-77° 1′	76° 58-59′	76° 58-59′	76° 59′-77°	76° 59′-77°	76° 58-59′	76° 58-59′
Latitude (North) ..	8° 22-23′	8° 22-23′	8° 24′	8° 24-25′	8° 23-24′	8° 23-24′	8° 24-25′	8° 24-25′
Depth in metres ..	10·5-11	9-10	10	6·5-7·5	5·5-8	4·5-5	5·5-7·5	8-9
Nature of bottom ..	Sandy	Sandy and Rocky	Sandy and Rocky	Rocky	Rocky	Rocky	Rocky	Rocky
Time of setting (hrs.) ..	17·40-17·50	16·45-16·55	16·35-16·45	16·59-16·57	16·00-16·07	16·30-16·40	16·30-16·40	16·45-16·55
Time of hauling (hrs.) ..	7·25-7·45	6·15-6·30	6·15-6·30	6·35-6·50	7·20-7·30	7·00-7·10	7·00-7·10	7·15-7·25
Condition of weather ..	Weak	Weak	Strong	Strong	Weak	Weak	Moderate	Moderate
Condition of sea ..	Calm	Calm	Calm	Calm	Light swell	Light swell	Calm	Calm
Condition of current ..	Weak	Weak	Weak	Weak	Weak	Weak	Weak	Weak
Total no. of lobsters ..	1	..	2	..	8	7	..	..
Total weight of all catch in kg. ..	18·60	47·61	22·68	6·80	8·17	9·75	2·27	14·61
Remarks ..								

APPENDIX IV

Fishing Log Sheet

Fishing Centre: Off Colachel and Muttam area. Fishing gear used: Bottom set gill nets.

Stations fished	1	2	3	4	5	6	7	8	9	10	11
Date of operation	7-8/1-60	7-8/1-60	8-9/1-60	9-10/1-60	9-10/1-60	11-12/1-60	11-12/1-60	12-13/1-60	12-13/1-60	15-16/1-60	15-16/1-60
Position Longitude (East)	77° 14-15′	77° 15-16′	77° 17′	77° 19′	77° 18-19′	77° 18-19′	77° 18-19′	77° 17′	77° 17-18′	77° 15′	77° 15-16′
Latitude (North)	8° 9-10′	8° 9′	8° 7-8′	8° 6-7′	8° 6-7′	8° 7-8′	8° 7′	8° 7-8′	8° 6-7′	8° 9′	8° 9′
Depth in metres ..	10-12	11-14	17·5-18·5	9	9·5-13	7·5-10	11-14	15·5-24	15-20	13-15	13-14
Bottom nature ..	Rocky	Rocky	Rocky	Rocky	Rocky	Rocky	Rocky	Rocky	Rocky	Rocky	Rocky
Time of setting (hrs.)	16·30-16·42	17·00-17·10	18·30-18·45	16·00-16·15	16·15-16·30	14·35-14·45	14·45-14·55	16·30-16·40	17·10-17·30	16·45-17·00	17·10-17·30
Time of hauling (hrs.)	6·30-6·55	14·10-14·30	6·30-6·50	7·15-7·35	7·45-8·05	6·30-6·50	6·45-7·05	6·30-6·45	7·00-7·15	6·30-6·40	7·00-7·10
Condition of weather	Fair	Fair	Fair	Fair	Fair	Fair	Fair	Fair	Fair	Fair	Fair
Condition of sea ..	Calm	Calm	Calm	Calm	Calm	Calm	Calm	Calm	Calm	Calm	Calm
Condition of current	Weak	Weak	Weak	Weak	Weak	Weak	Weak	Weak	Weak	Weak	Weak
Total No. of lobsters	5	6	..	9	16	2	..	..	..	..	..
Total wt. of catch in kg.	42·19	4·20	13·95	18·84	64·98	11·34	2·72	7·45	4·08	9·07	..
Remarks ..											

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The drawing on the Cover Page depicts a chank fishing scene off the South-East coast of India. The Indian sacred chank, Xancus pyrum *(Linnaeus) which supports the fishery in this region and elsewhere along the Indian coast is shown in the inset below.*

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